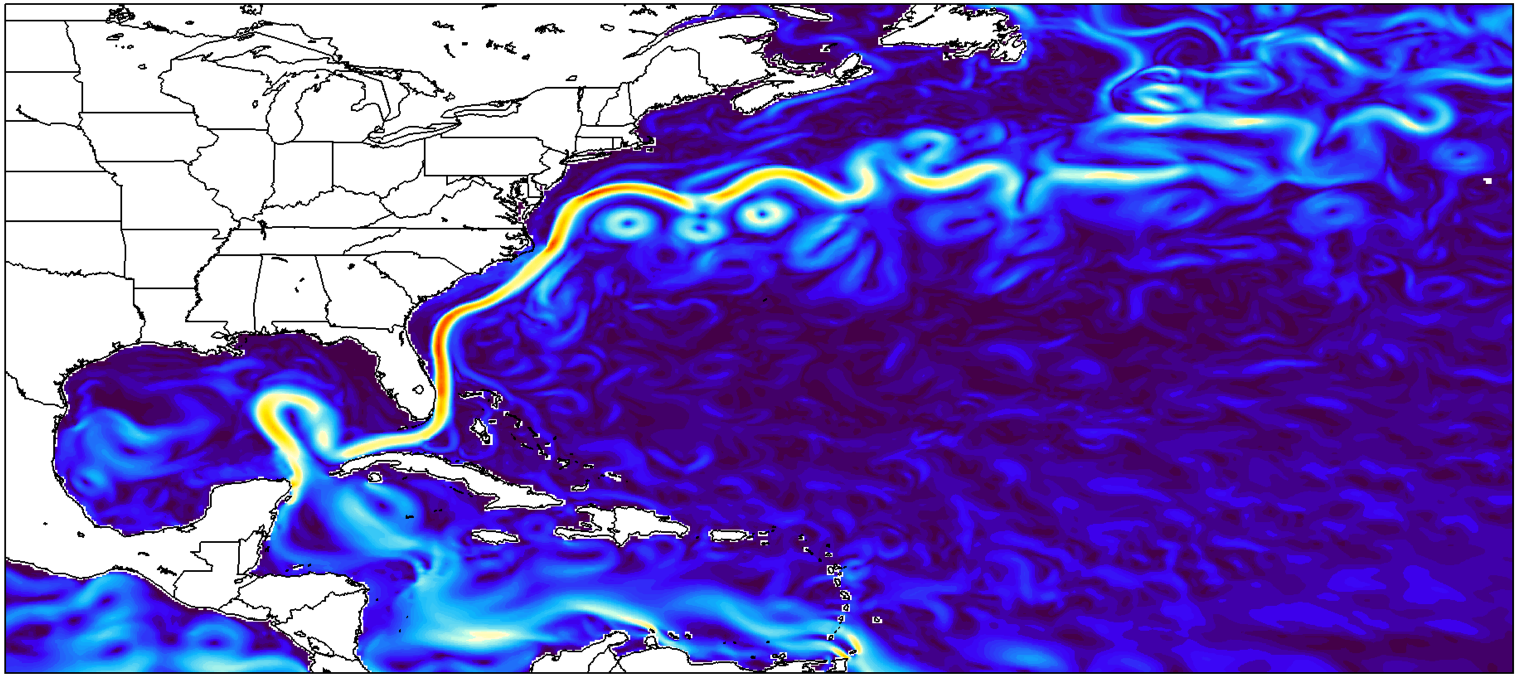
UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

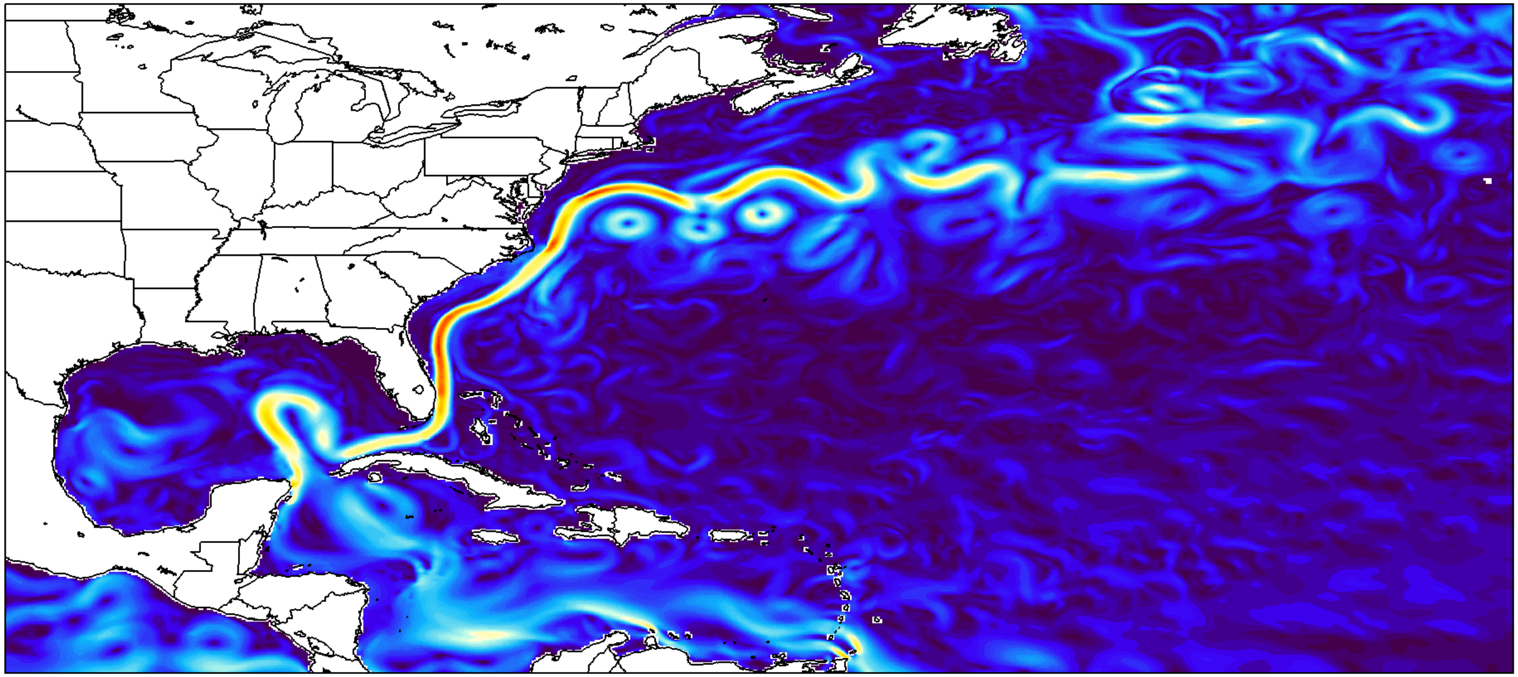
CENTER FOR COMPUTATIONAL SCIENCE
UNIVERSITY OF MIAMI

Impact of Ocean Model Resolution on CCSM4 Simulations



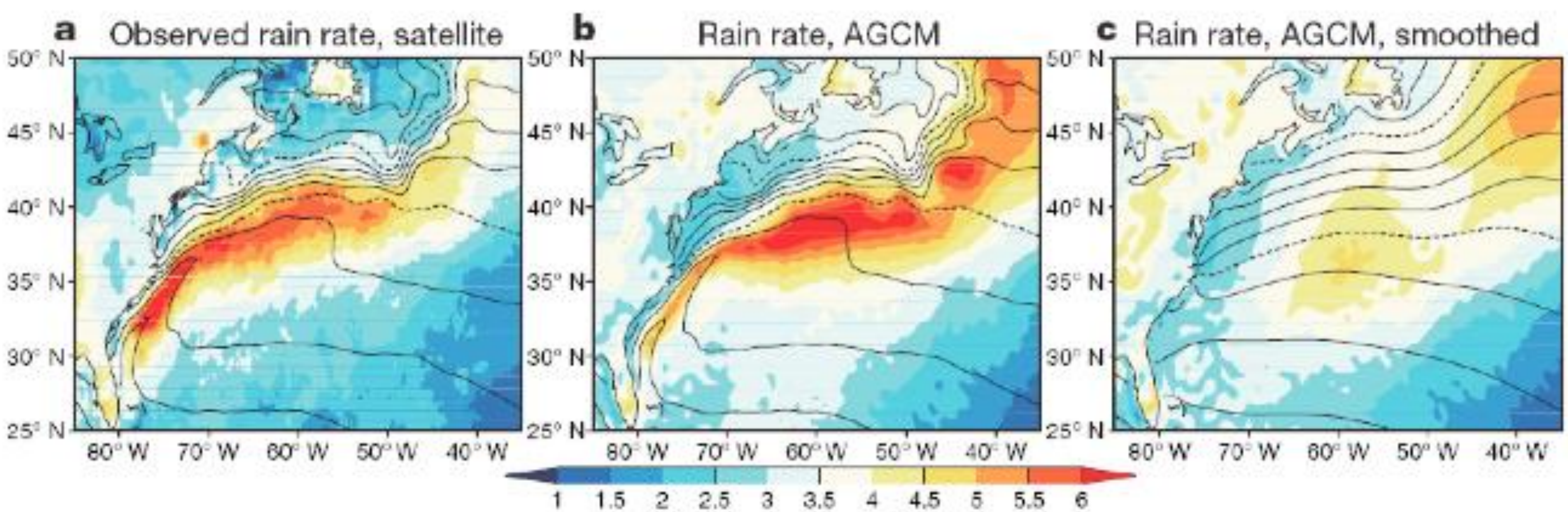
“Peta-Apps”-Team

Ben P. Kirtman, Cecilia Bitz, Frank Bryan, William Collins, John Dennis, Nathan Hearn, James L. Kinter III, Richard Loft, Clem Rousset, Ben Shaw, Leo Siqueira, Cristiana Stan, Robert Tomas and Mariana Vertenstein



Outline

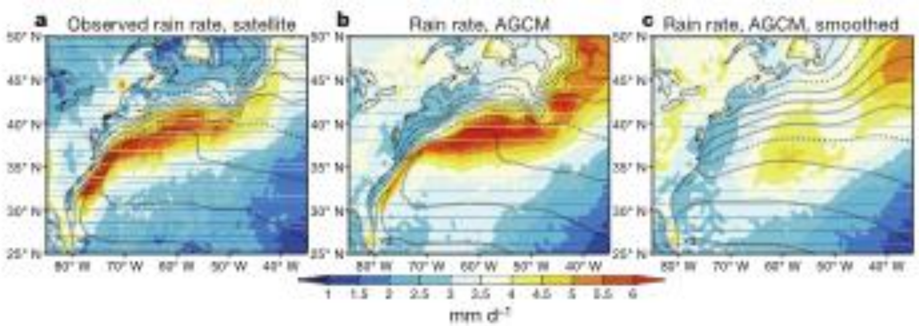
- **Motivation:**
  - **Scale Interactions – How Do Ocean Eddies Impact the Large Scale Climate?**
  - **Minobe et al. (2008) - Nature**
  - **Number of Previous Studies Focused on Atmospheric Resolution**
  - **Recent focus on the Importance of Ocean Eddies**
    - **Toniazzo et al. (2009); Zheng et al (2009); McWilliams and Colas (2010)**
  - **McClean et al. (2010); Bryan et al. (2010)**
    - **Order 10-20 Year Simulations**



Outline

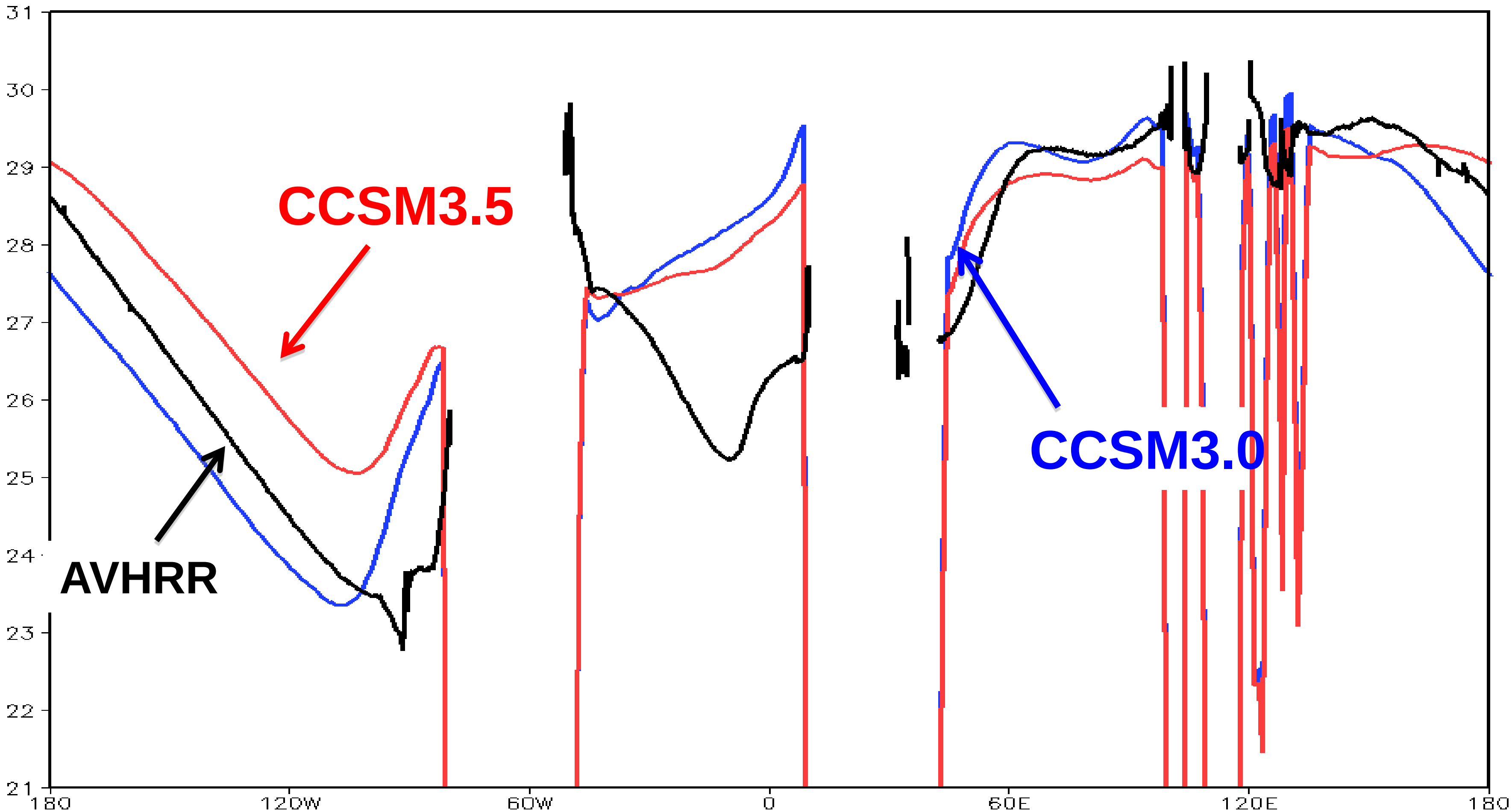
- **CCSM4***
  - **Atmosphere: 0.5x0.5**
  - **Two Versions: 1x1 [LRC] and 0.1x0.1 [HRC*]**
  - **Initialization: Spun-Up Ocean, Interpolation**
- **Analysis To Date Largely Focused on Global Climate and Air-Sea Feedback**
  - **Global Perspective (Global Survey)**
  - **Regional Highlights: North Atlantic, North Pacific, Tropical Pacific, Tropical Atlantic**
  - **Coupled Feedback: Does the Coupling Matter???**
- **Movie, Future Work and Remarks**

Not Coupled

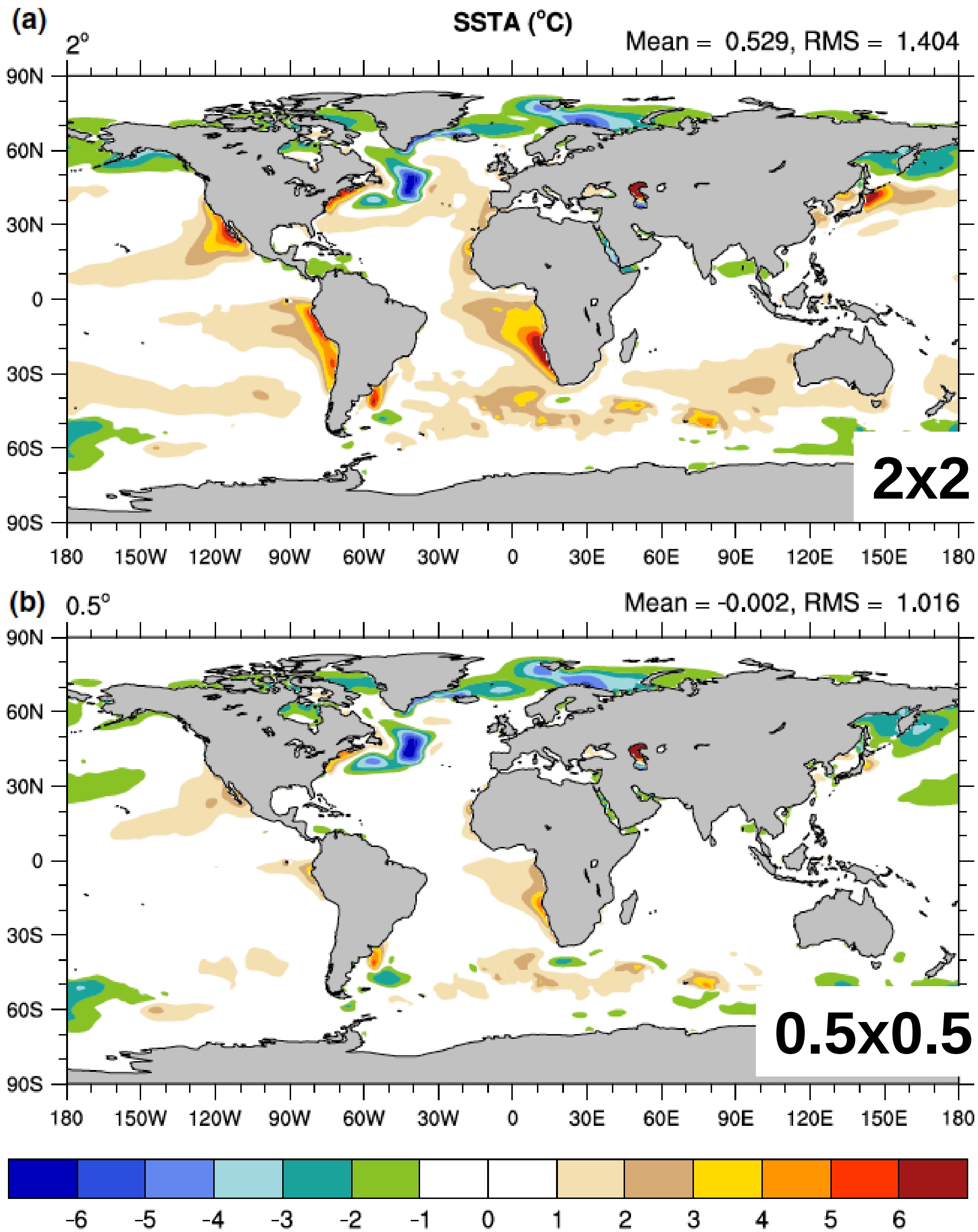


Affect of Improved Parameterized Physics

- CCSM3.0 vs CCSM3.5
  - Atmosphere: T85; Ocean 1x1

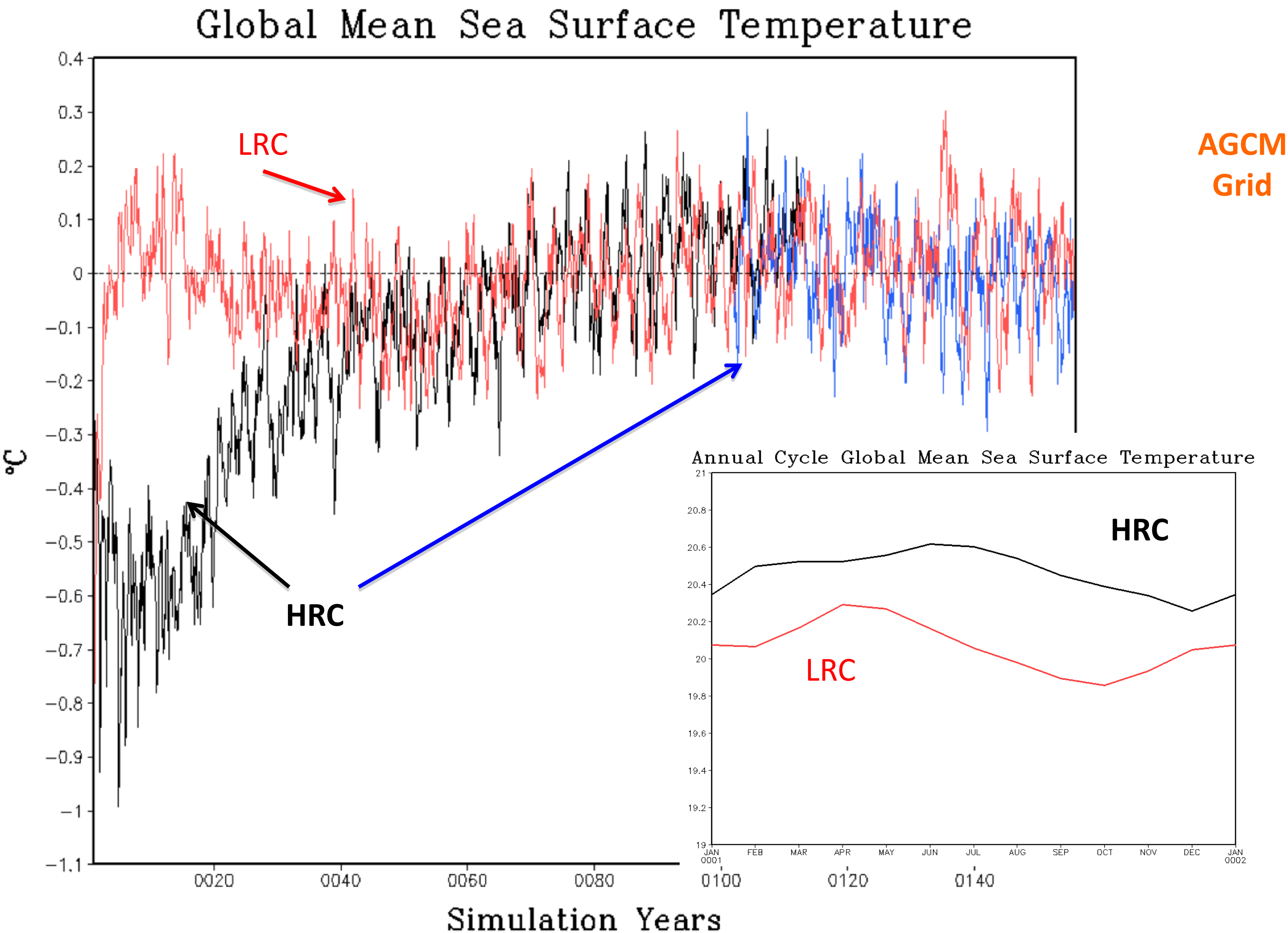


Climatological Equatorial SST



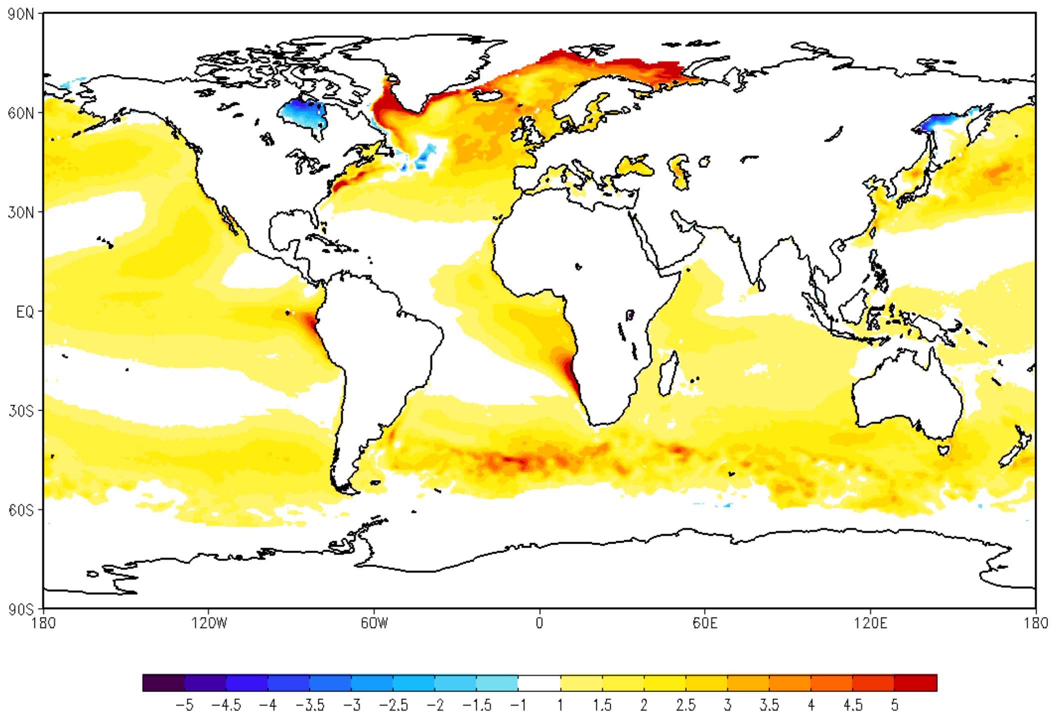
Increasing AGCM Resolution: 2x2 vs 0.5x0.5

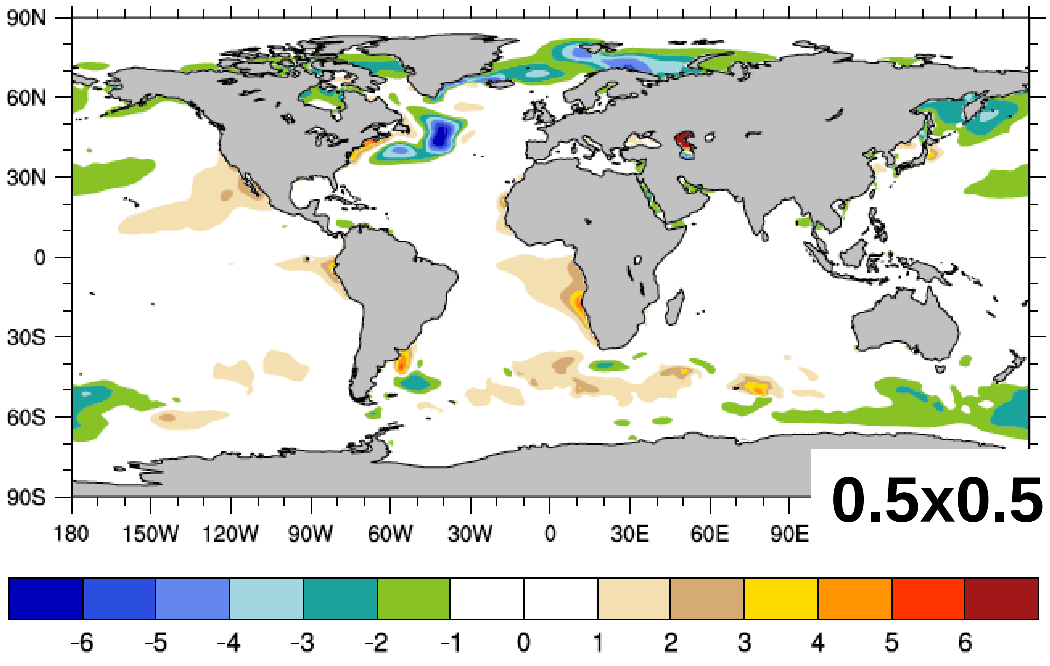
Gent et al. 2010



Global Mean Sea Surface Temperature
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1
−1.1
°C
LRC
HRC
AGCM
Grid
0020
0040
0060
0080
0100
0120
0140
Simulation Years
Annual Cycle Global Mean Sea Surface Temperature
21
20.8
20.6
20.4
20.2
20
19.8
19.6
19.4
19.2
19
JAN 0001
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN 0002
HRC
LRC

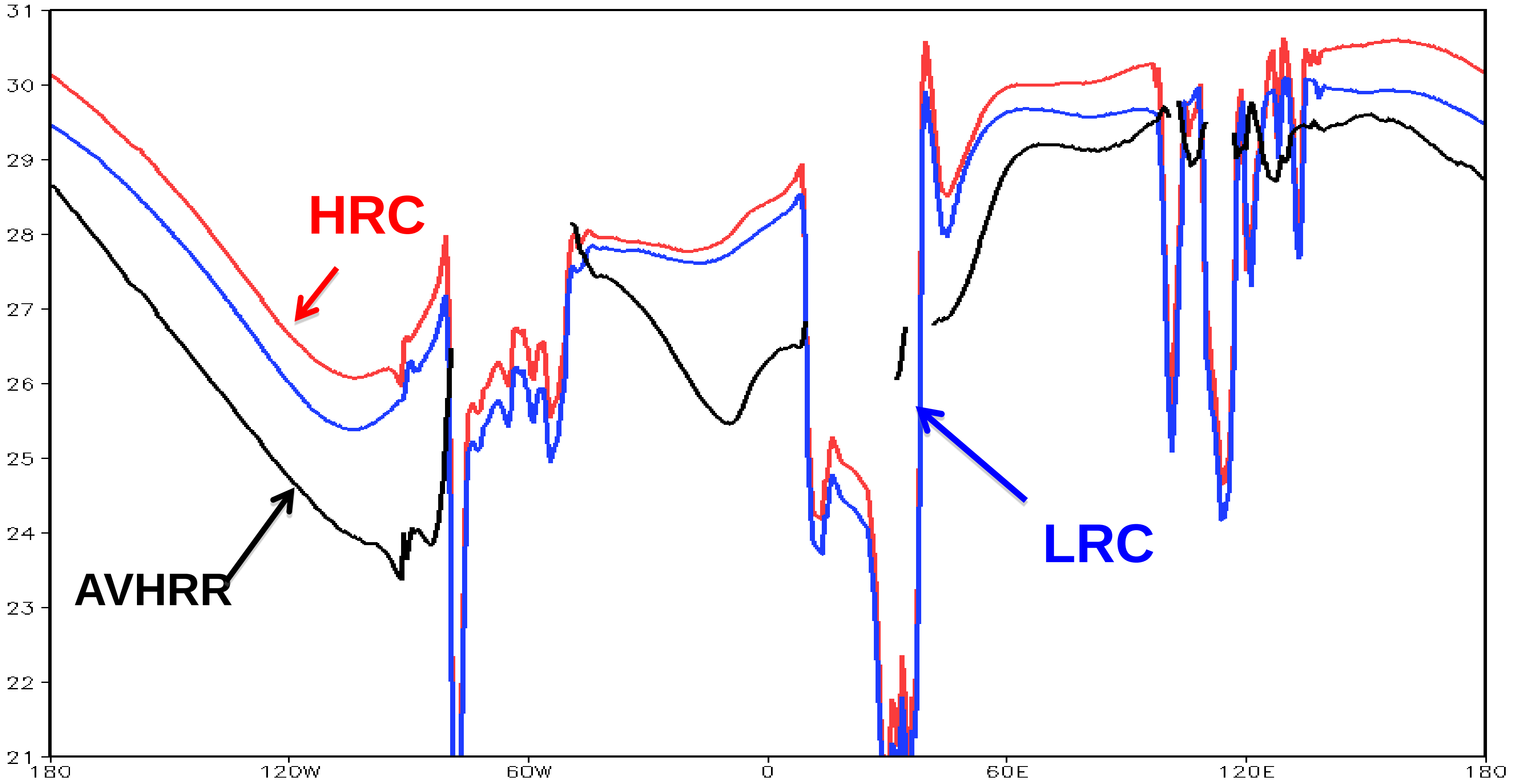
Increasing OGCM Resolution: Eddy Permitting vs. Resolving



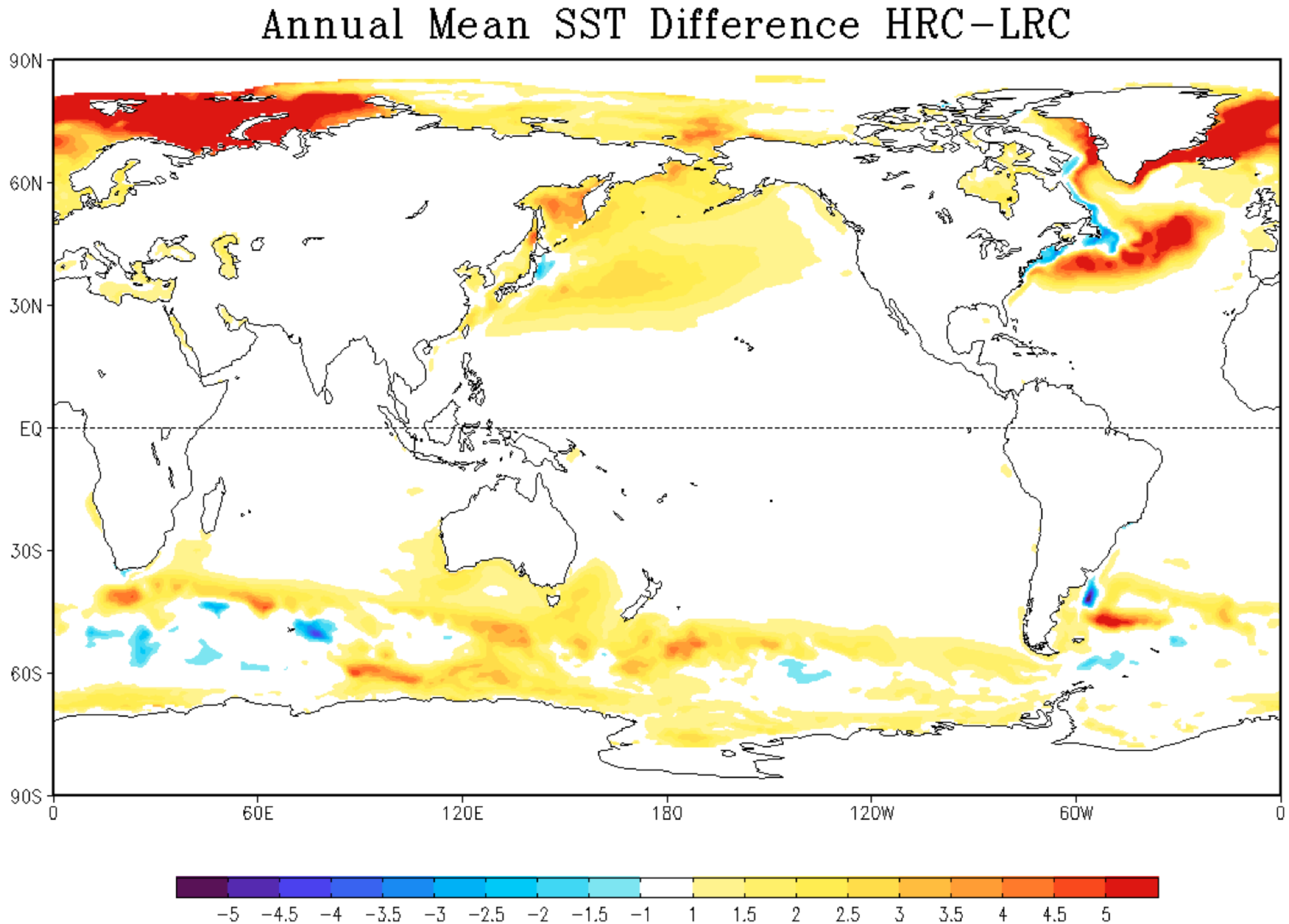


Affect of Resolved Ocean Eddies

- CCSM4
  - Atmosphere: 0.5x0.5
  - Two Versions: 1x1 [LRC] and 0.1x0.1 [HRC]

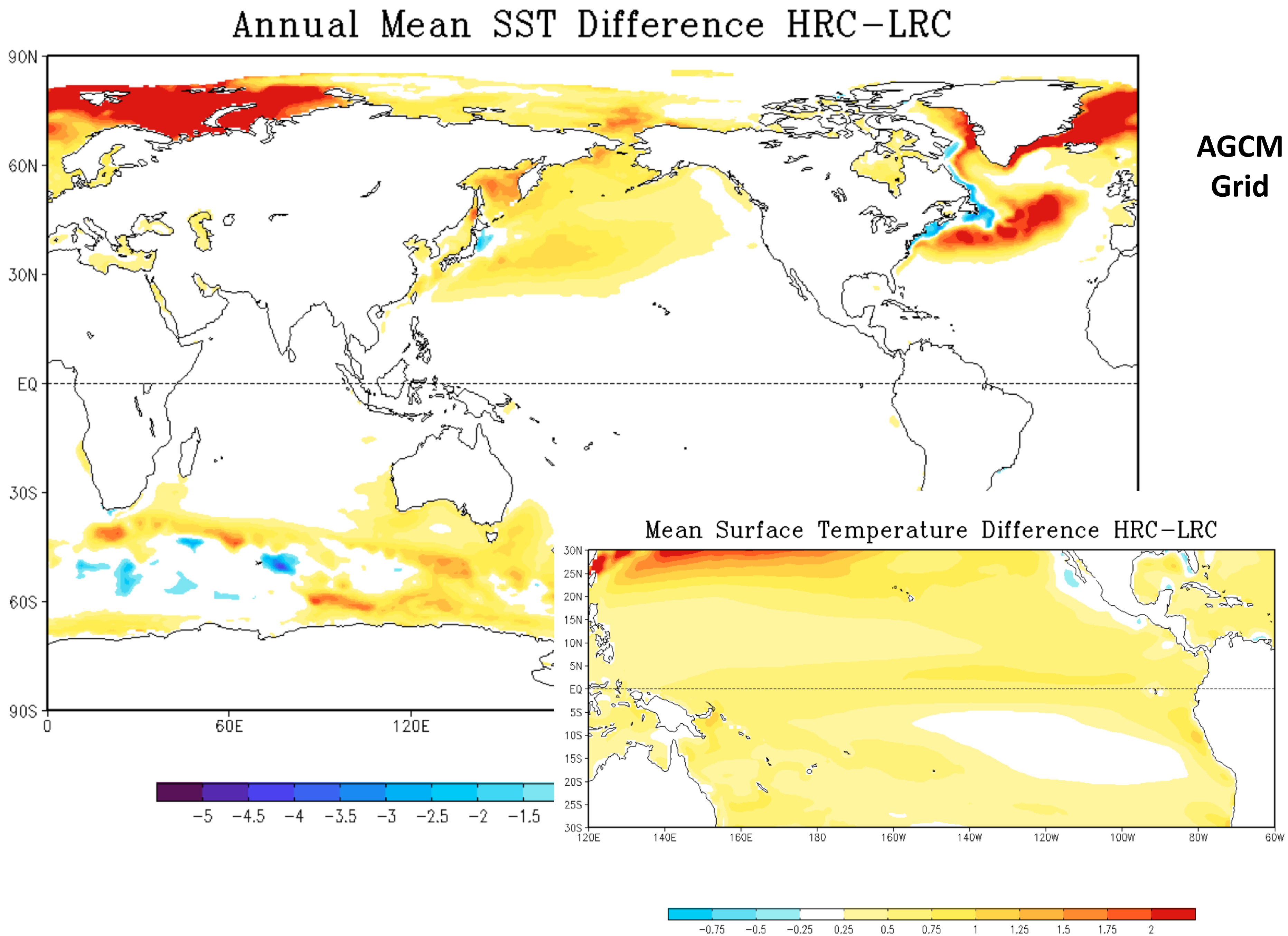


Climatological Equatorial SST



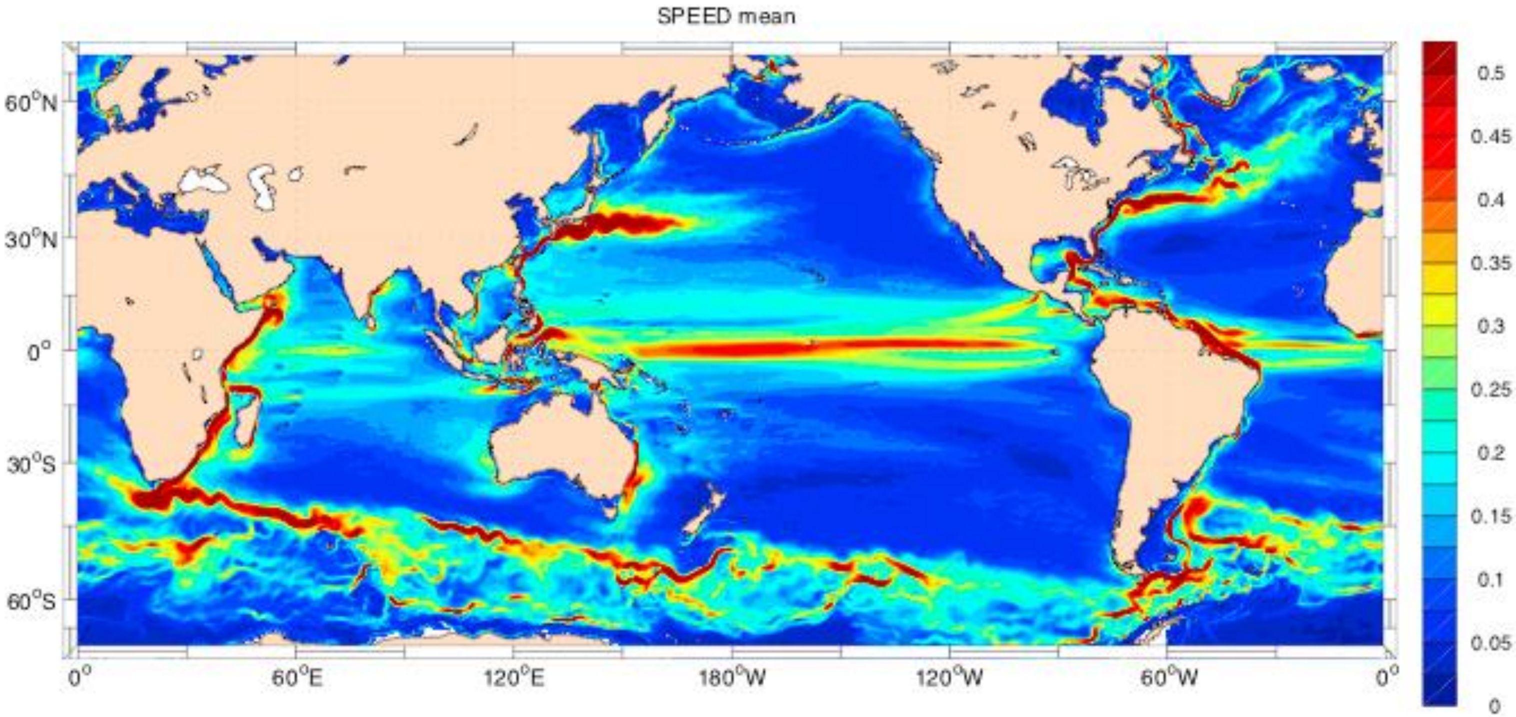
Annual Mean SST Difference HRC−LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−5
−4.5
−4
−3.5
−3
−2.5
−2
−1.5
−1
1
1.5
2
2.5
3
3.5
4
4.5
5

AGCM Grid

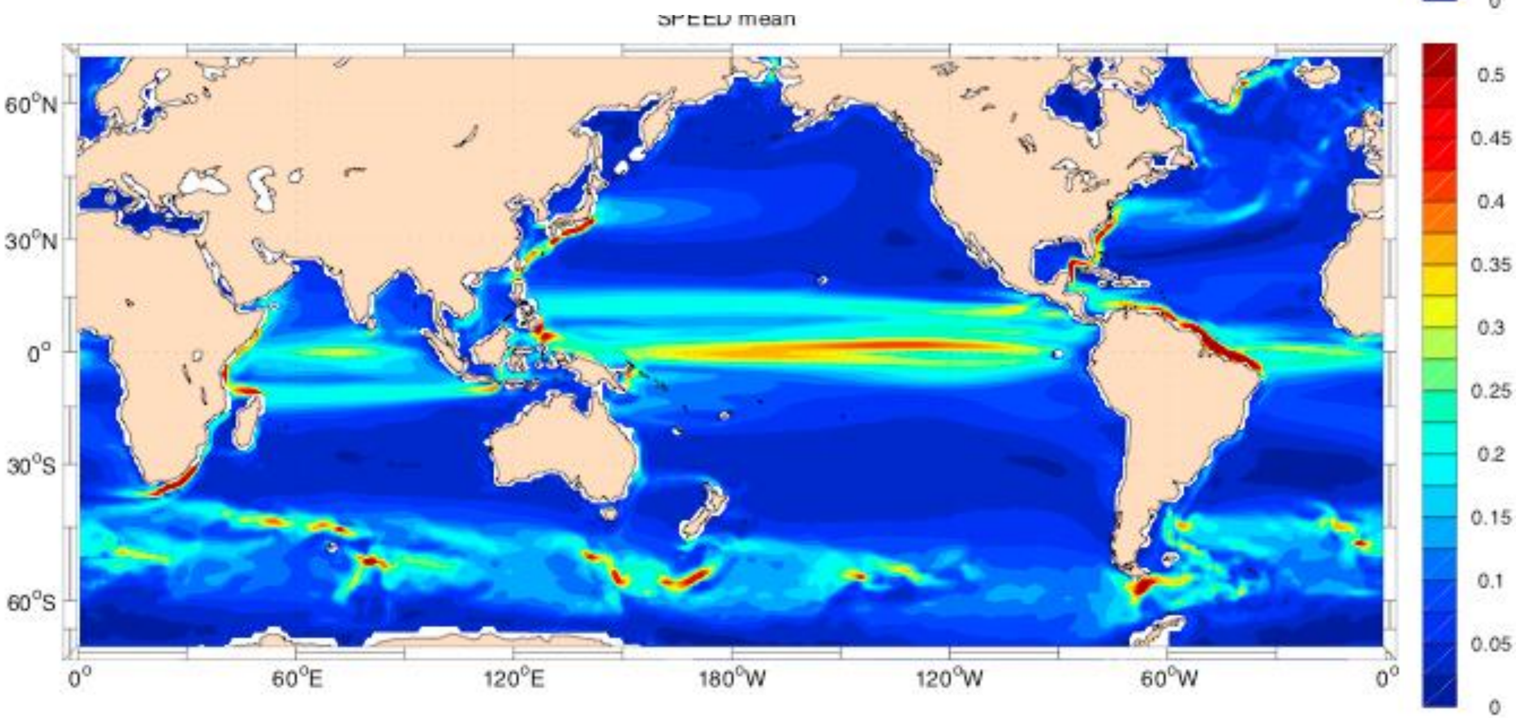

Annual Mean SST Difference HRC−LRC
Mean Surface Temperature Difference HRC−LRC
−5 −4.5 −4 −3.5 −3 −2.5 −2 −1.5
−0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.25 1.5 1.75 2

AGCM Grid

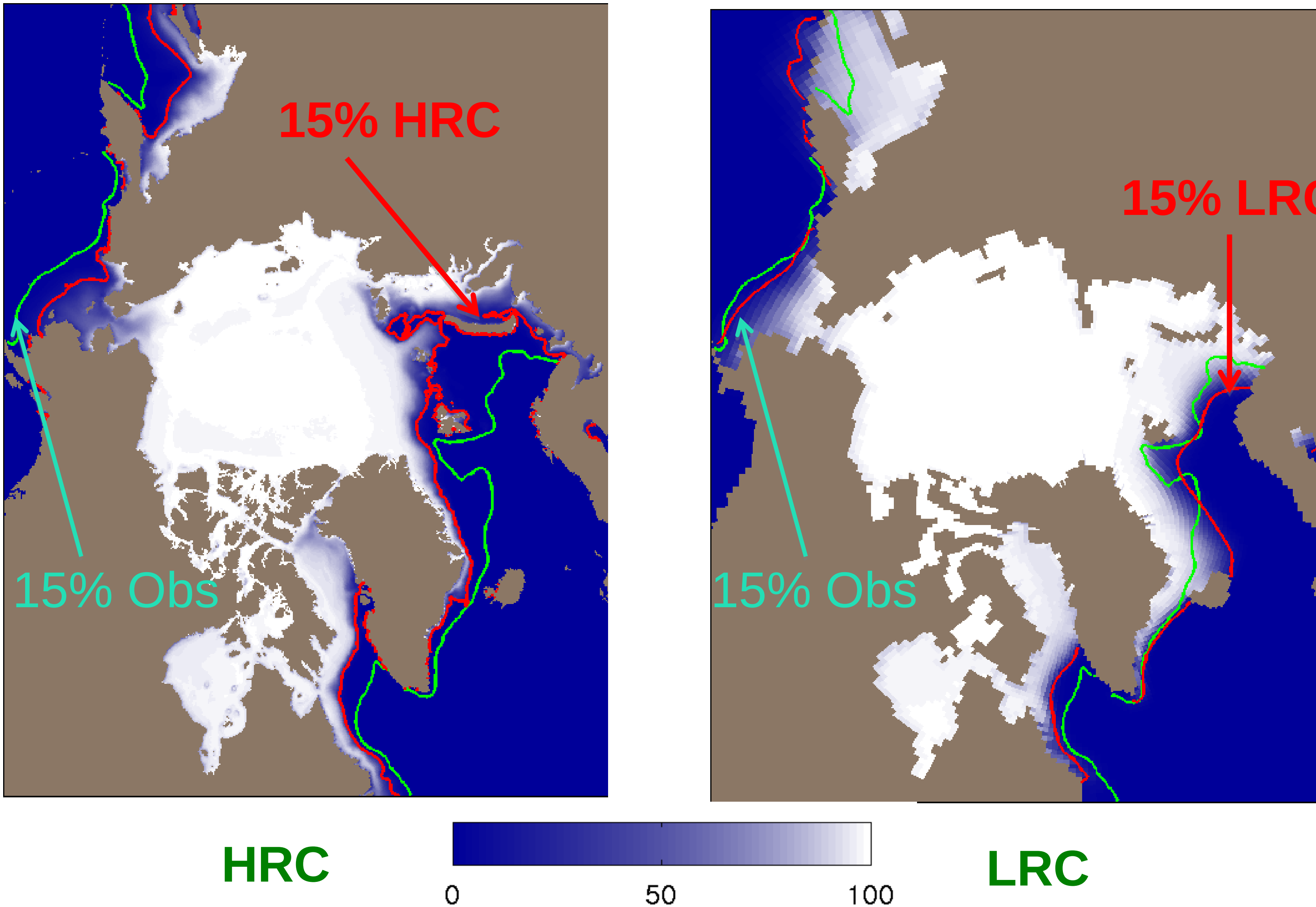
HRC


SPEED mean
60°N
30°N
0°
30°S
60°S
0°
60°E
120°E
180°W
120°W
60°W
0°
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0

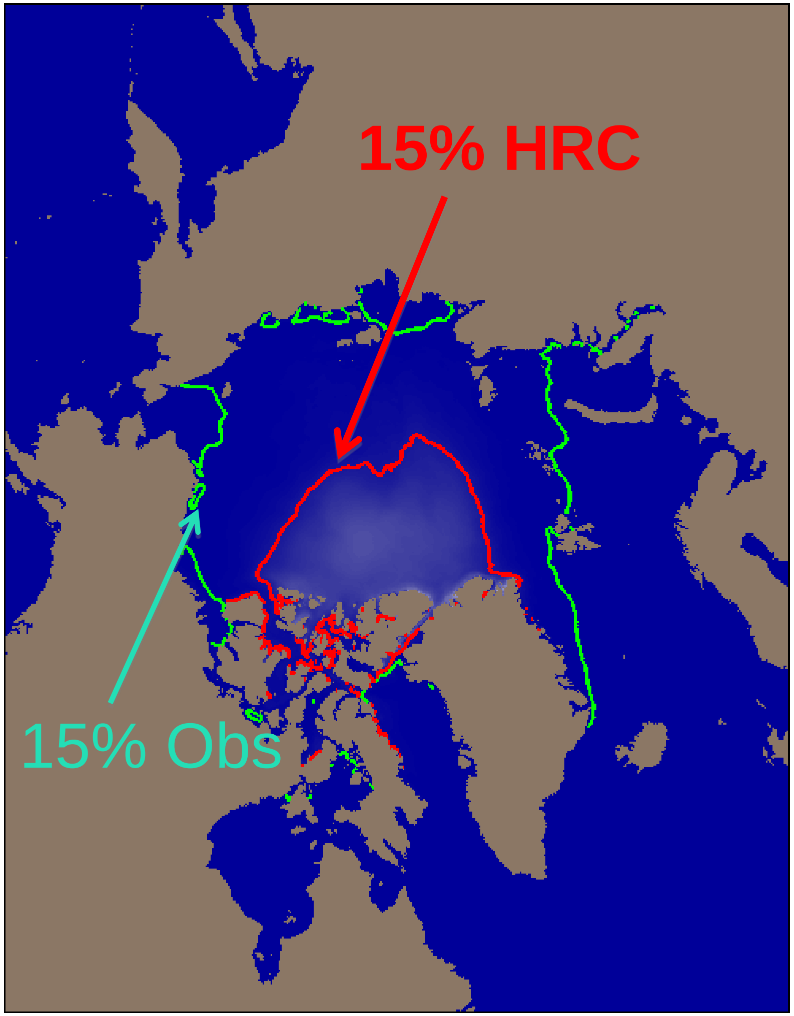
LRC

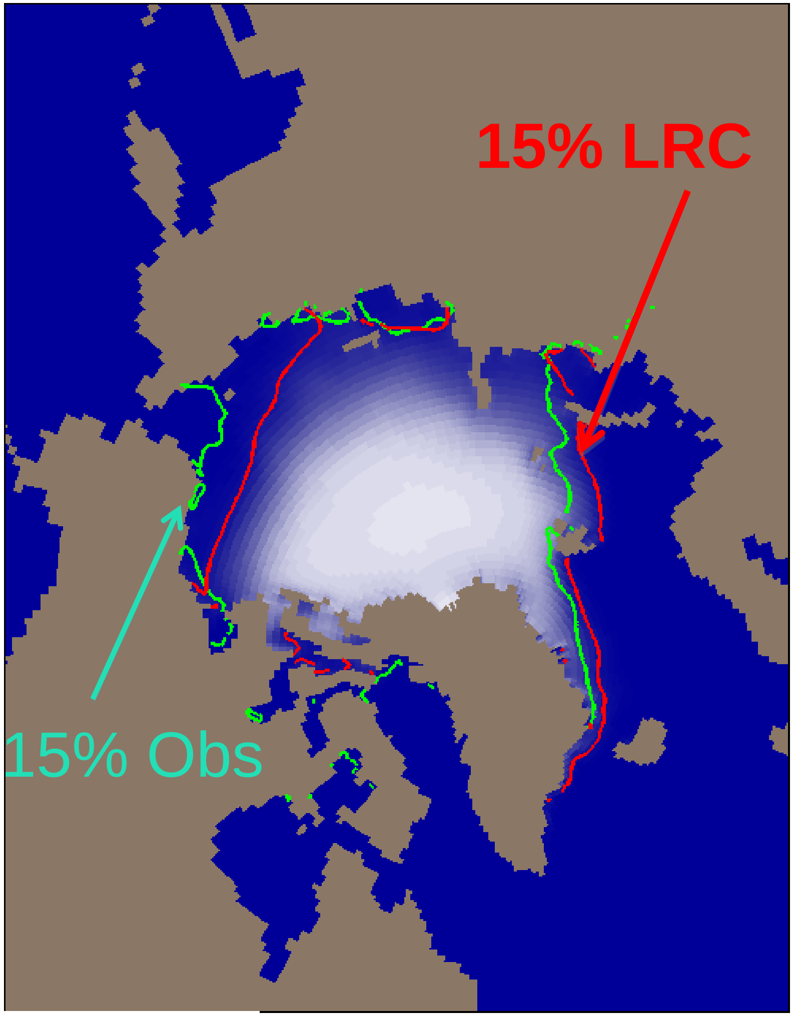

SPEED mean
60°N
30°N
0°
30°S
60°S
0°
60°E
120°E
180°W
120°W
60°W
0°
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0

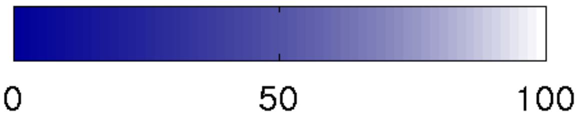
March Sea Ice Concentrations



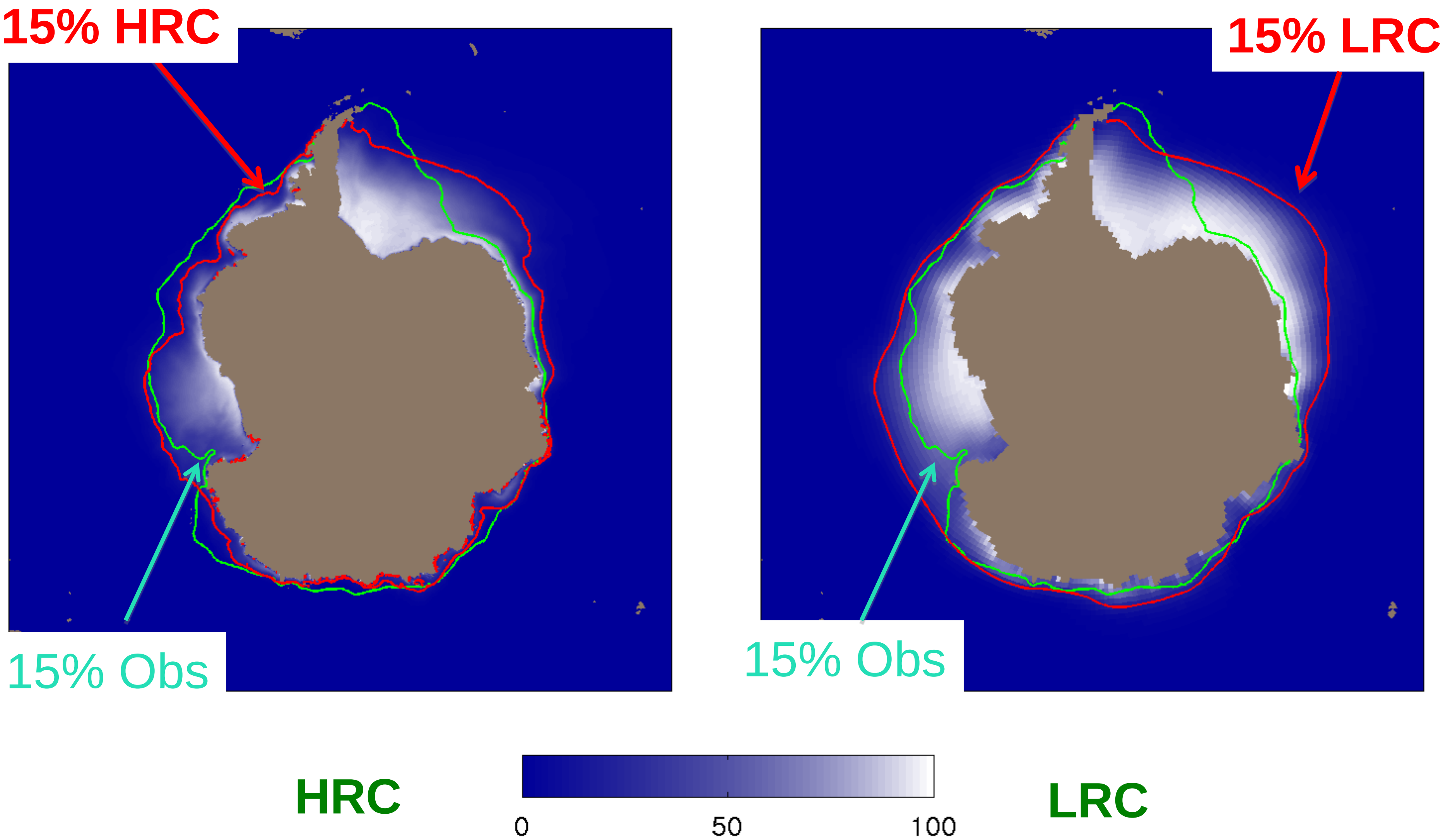
September Sea Ice Concentrations



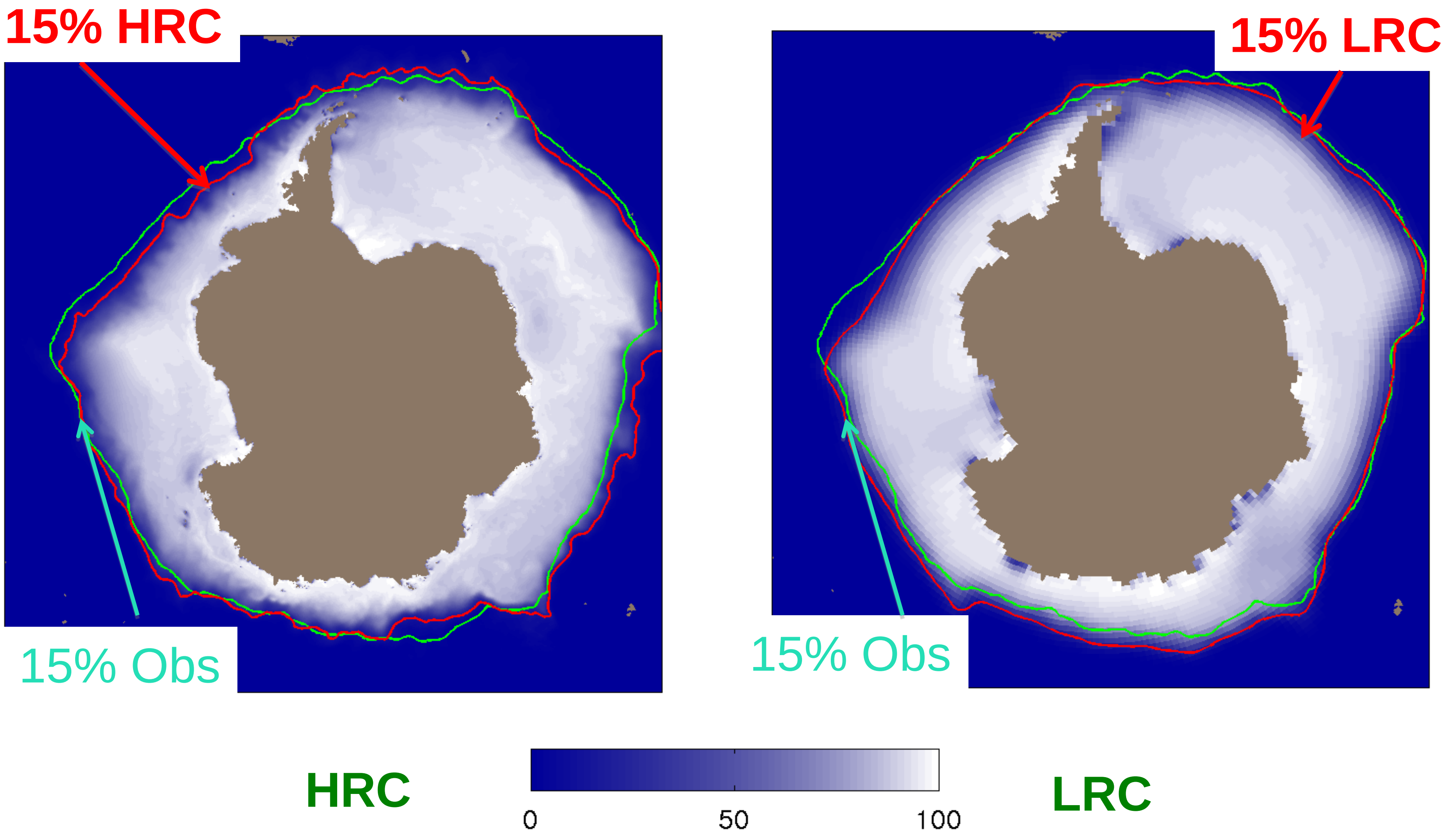




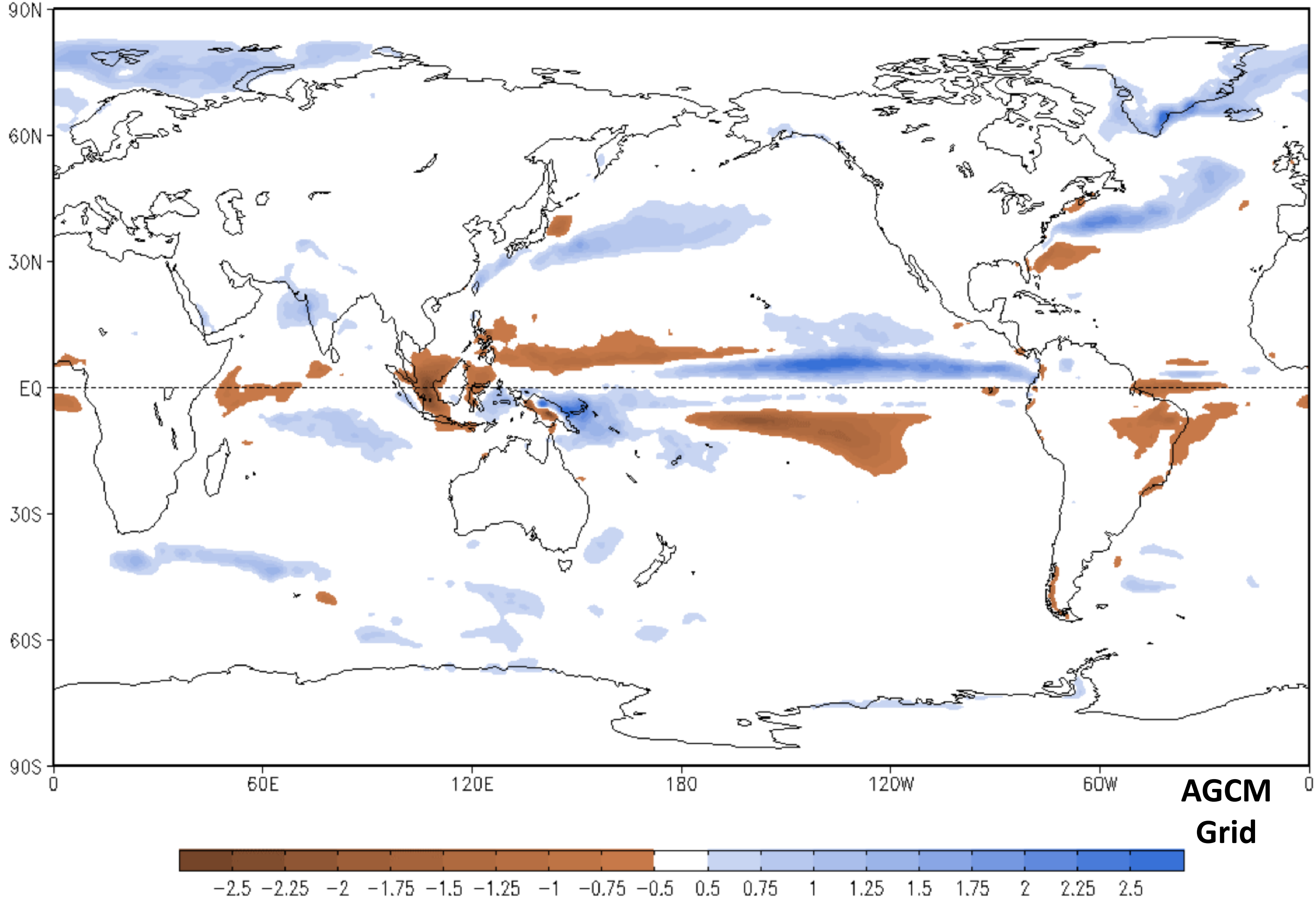
March Sea Ice Concentrations



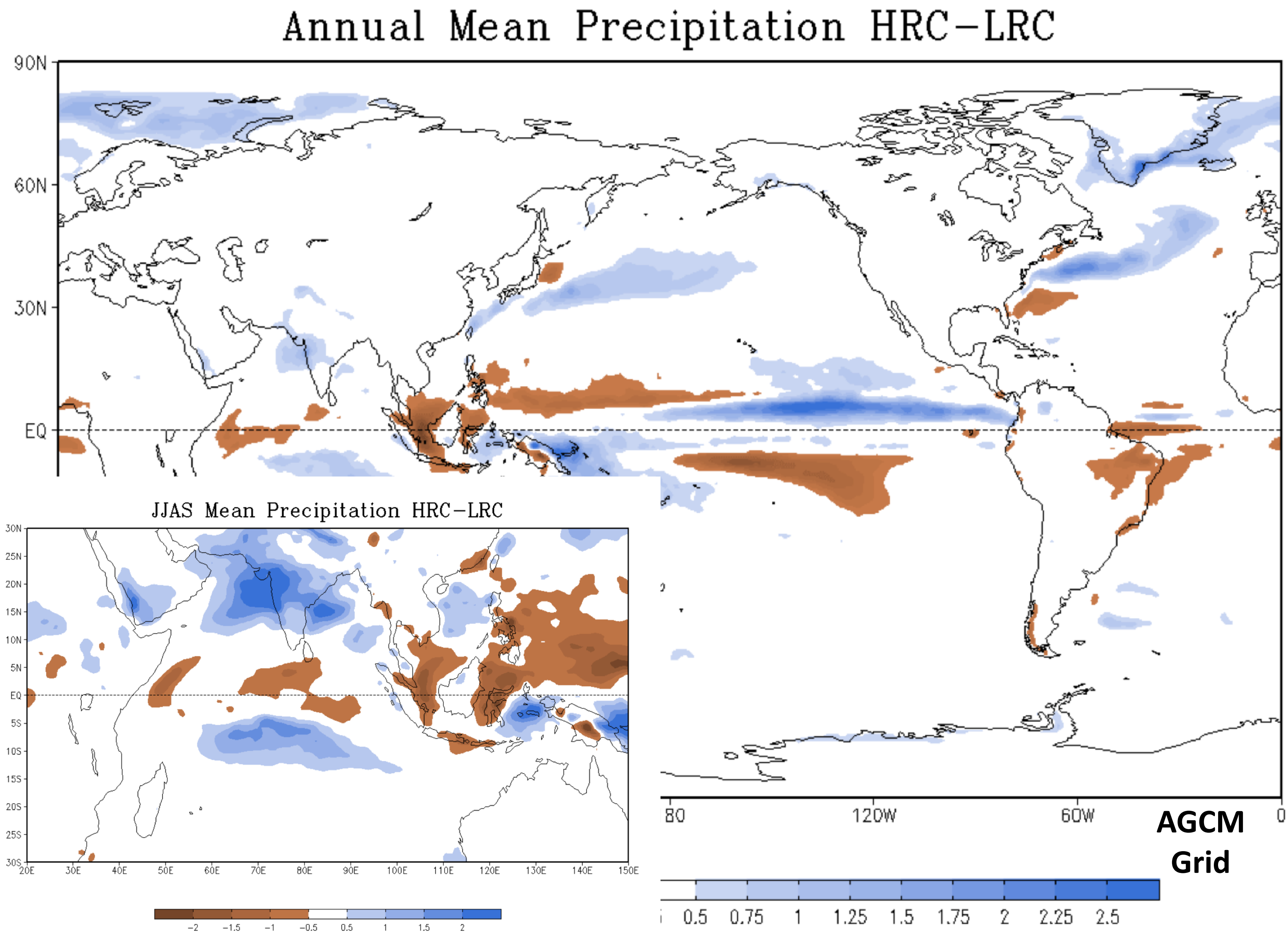
September Sea Ice Concentrations



Annual Mean Precipitation HRC-LRC

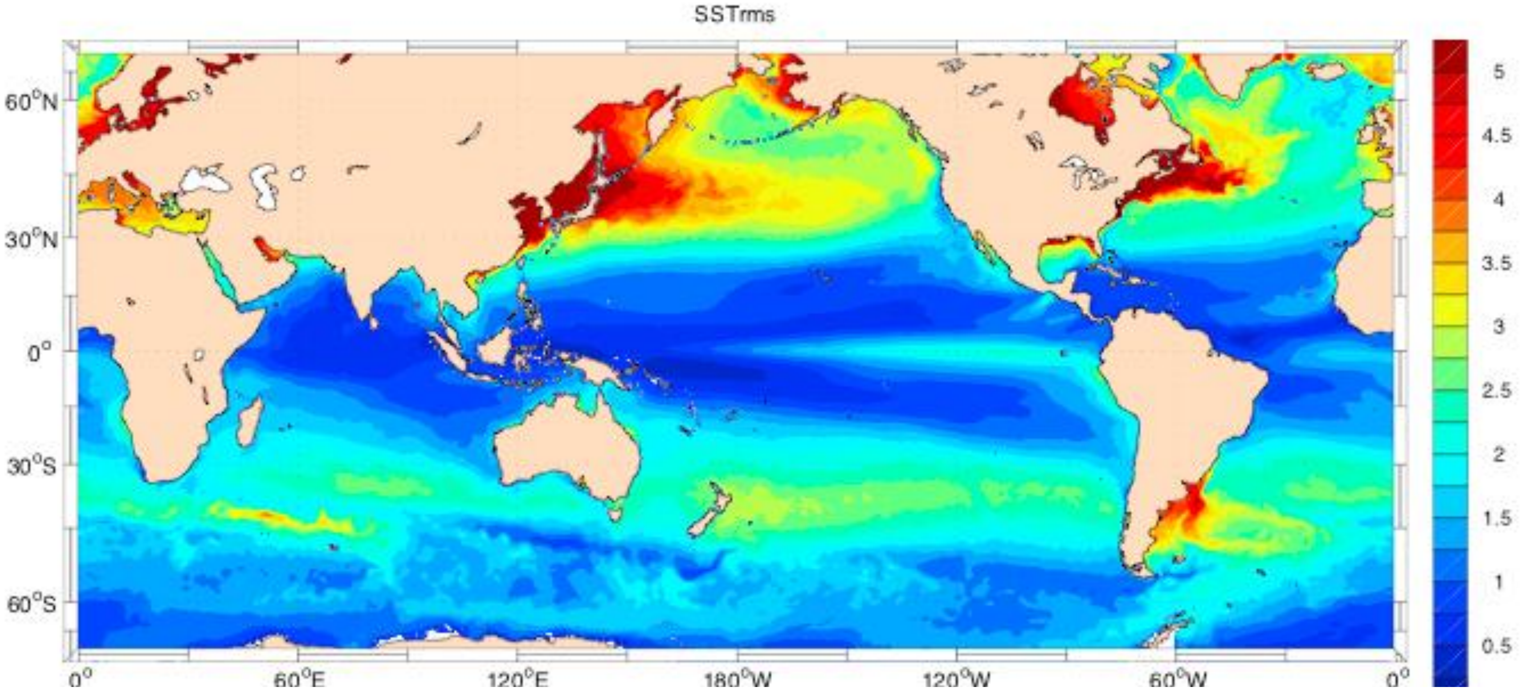


AGCM Grid

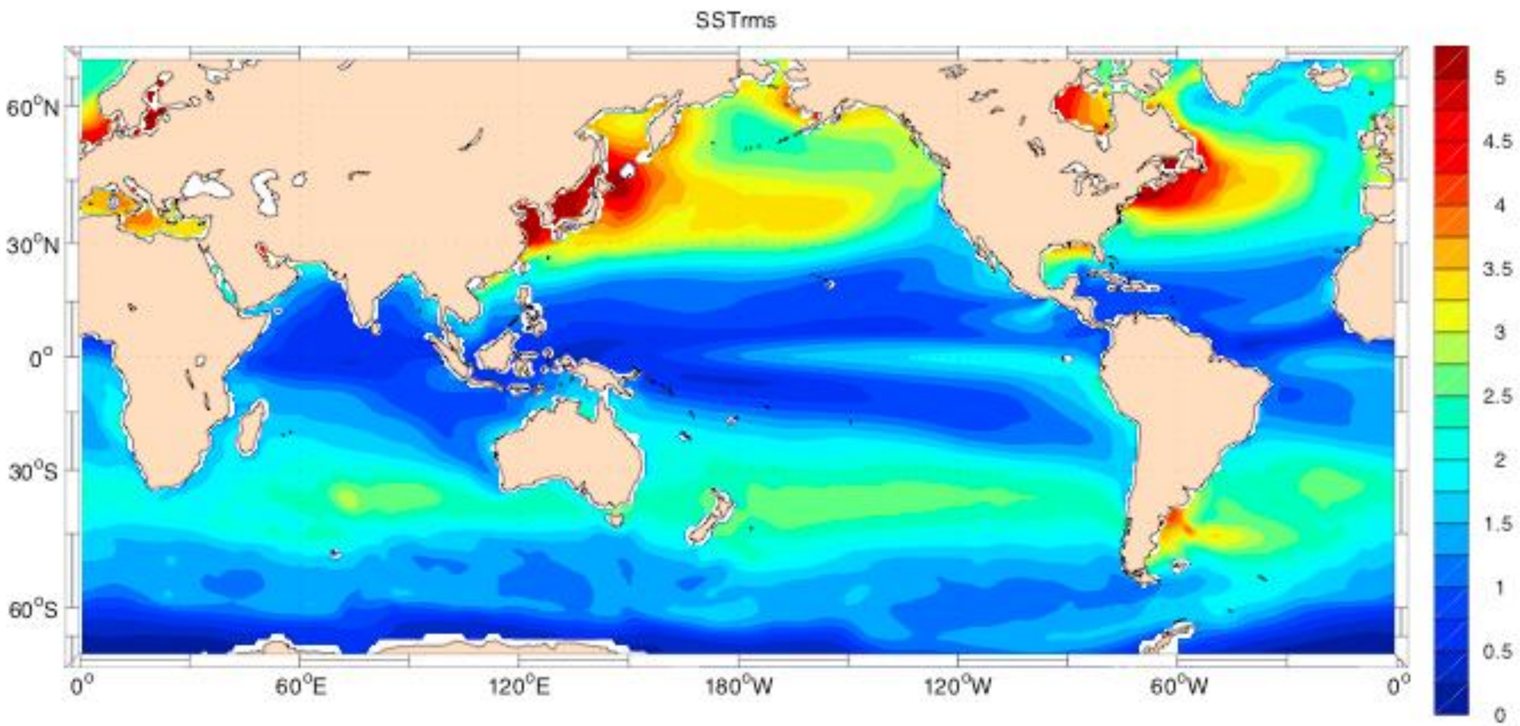

Annual Mean Precipitation HRC−LRC
90N
60N
30N
EQ
80
120W
60W
0
0.5 0.75 1 1.25 1.5 1.75 2 2.25 2.5
JJAS Mean Precipitation HRC−LRC
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
20E 30E 40E 50E 60E 70E 80E 90E 100E 110E 120E 130E 140E 150E
−2 −1.5 −1 −0.5 0.5 1 1.5 2

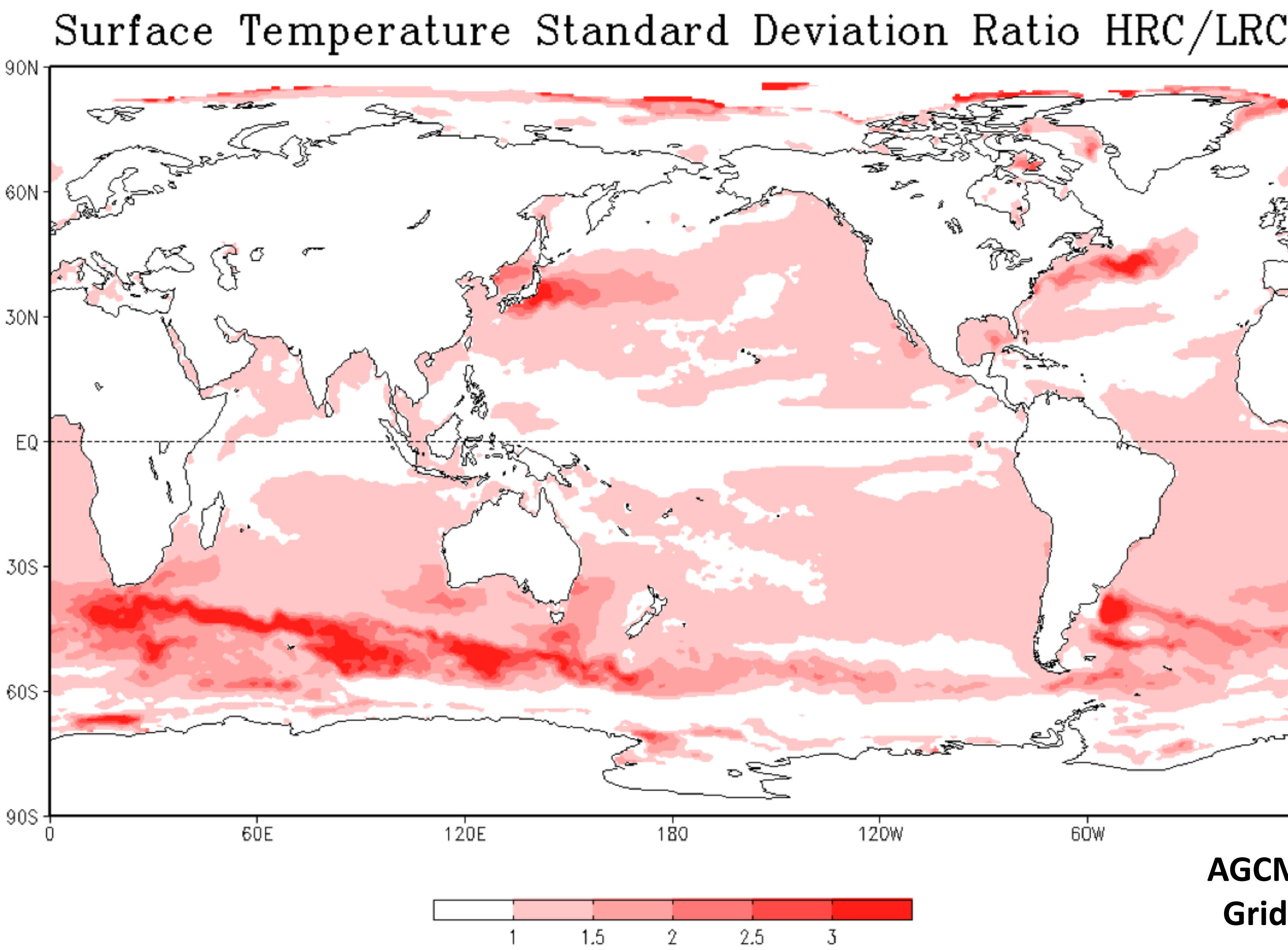
AGCM Grid

HRC


SSTrms
60°N
30°N
0°
30°S
60°S
0°
60°E
120°E
180°W
120°W
60°W
0°
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5

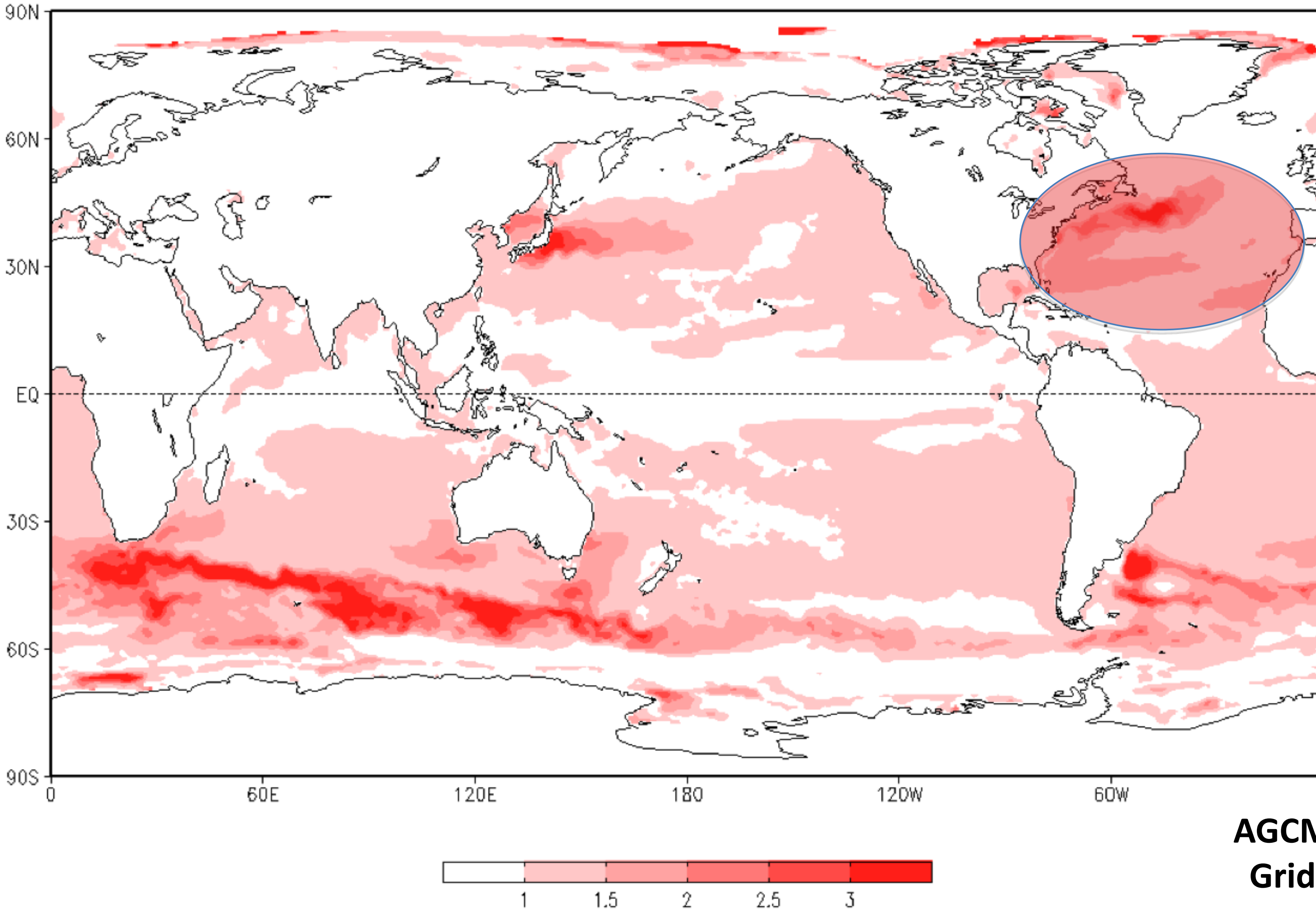
LRC


SSTrms
60°N
30°N
0°
30°S
60°S
0°
60°E
120°E
180°W
120°W
60°W
0°
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

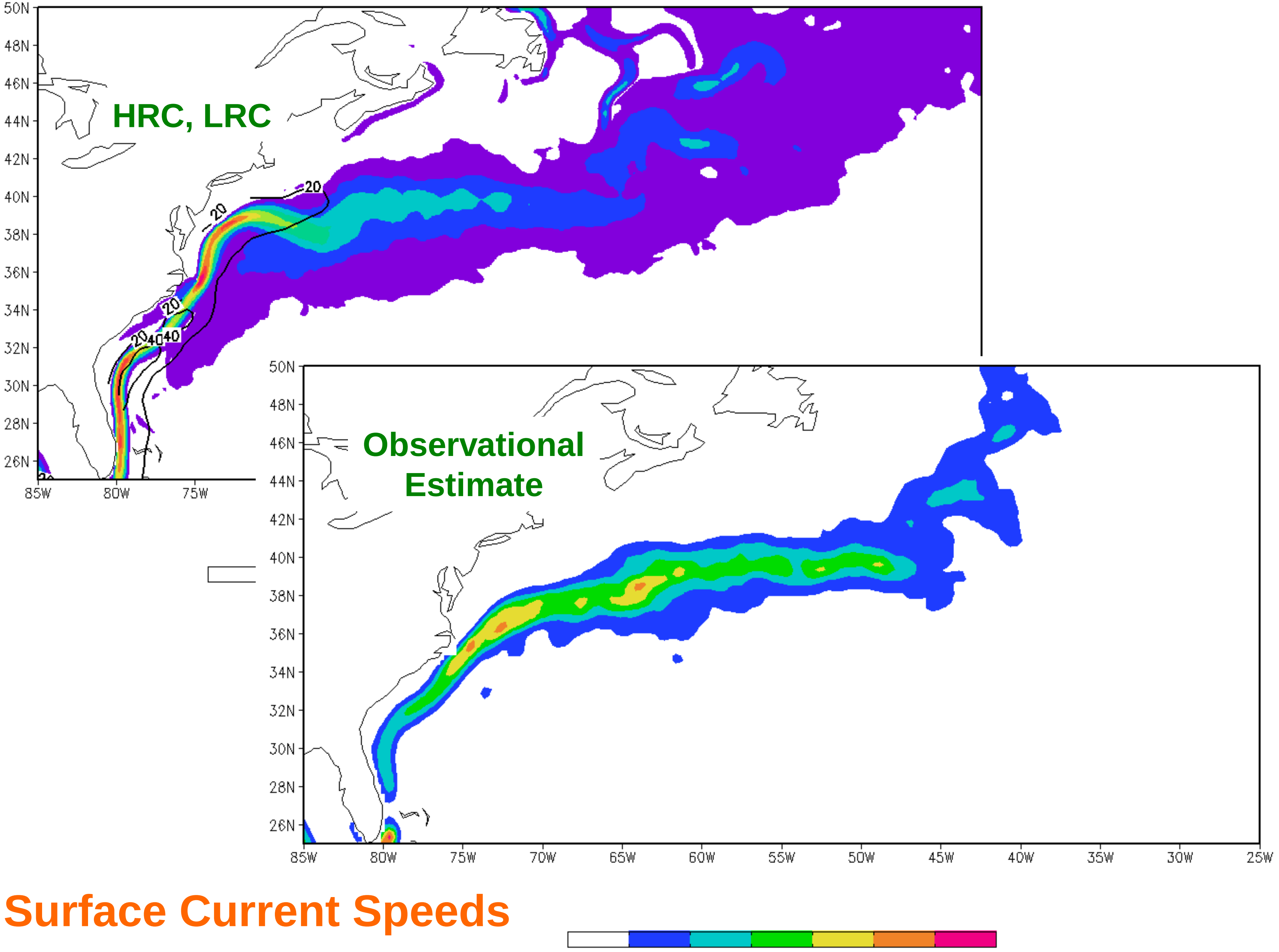

Surface Temperature Standard Deviation Ratio HRC/LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
1
1.5
2
2.5
3

AGCM Grid

Surface Temperature Standard Deviation Ratio HRC/LRC

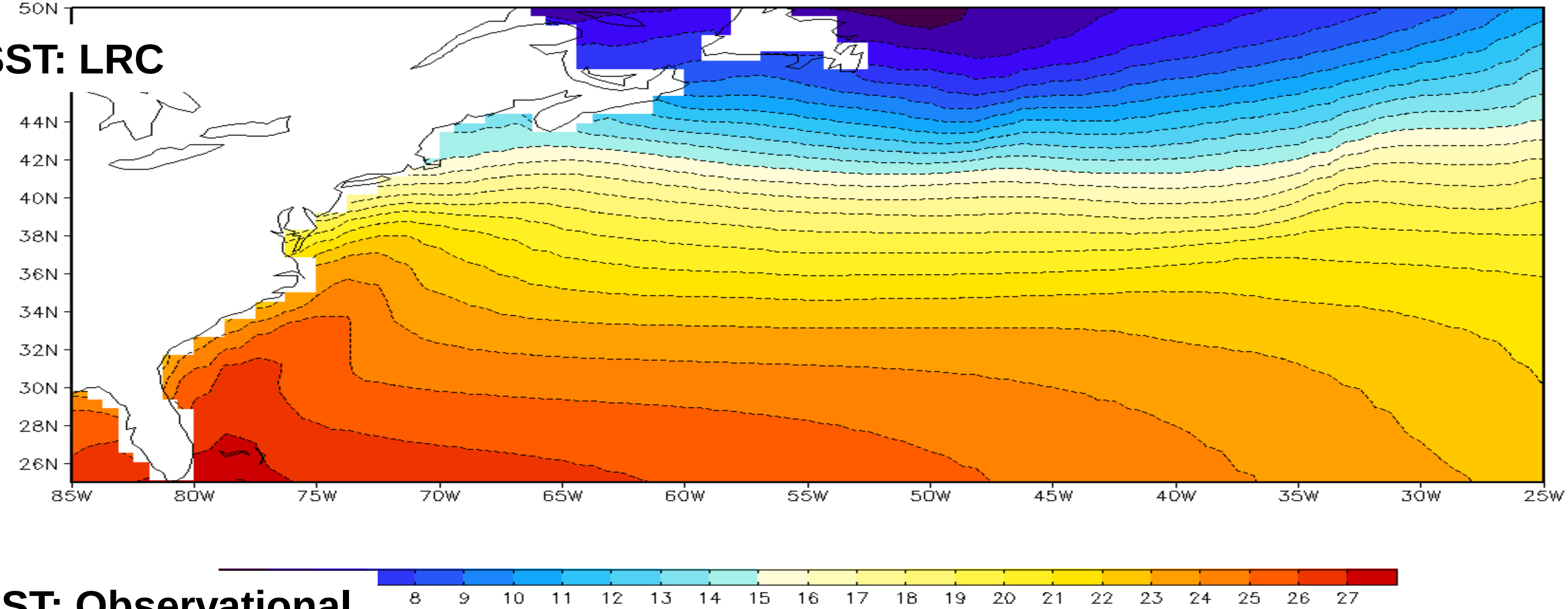


AGCM Grid

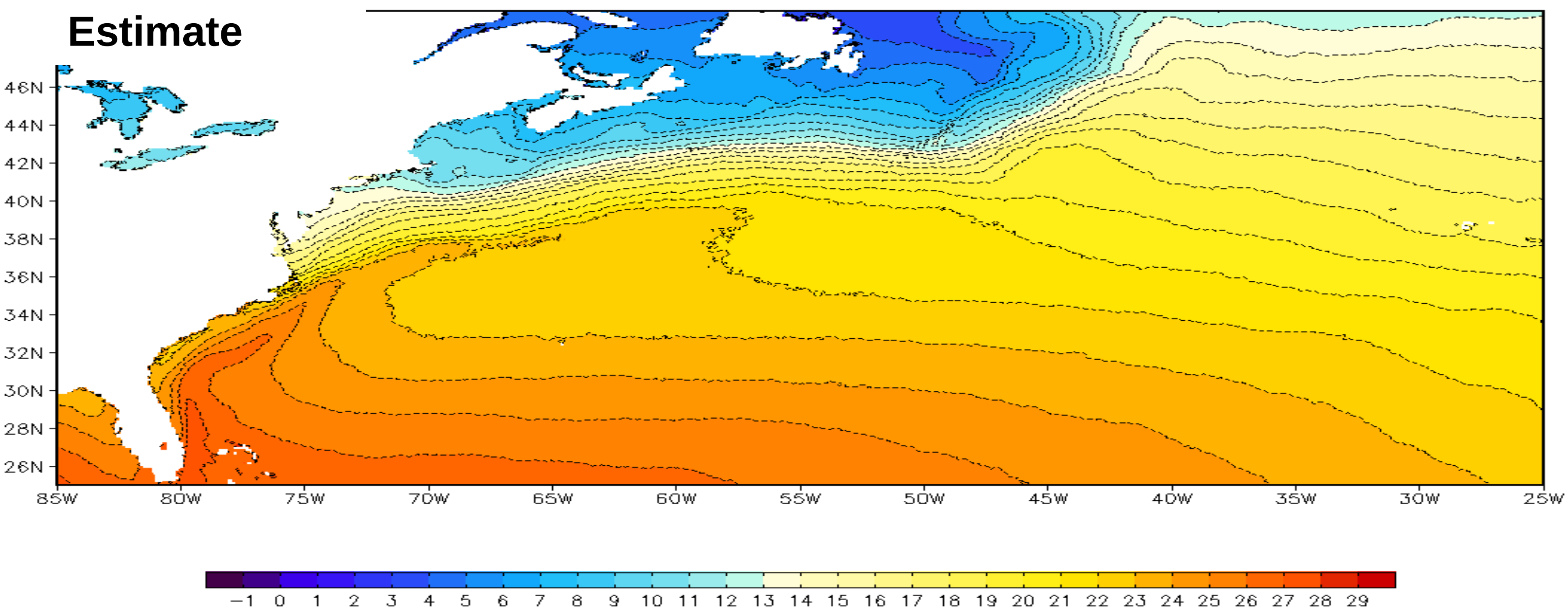


Surface Current Speeds

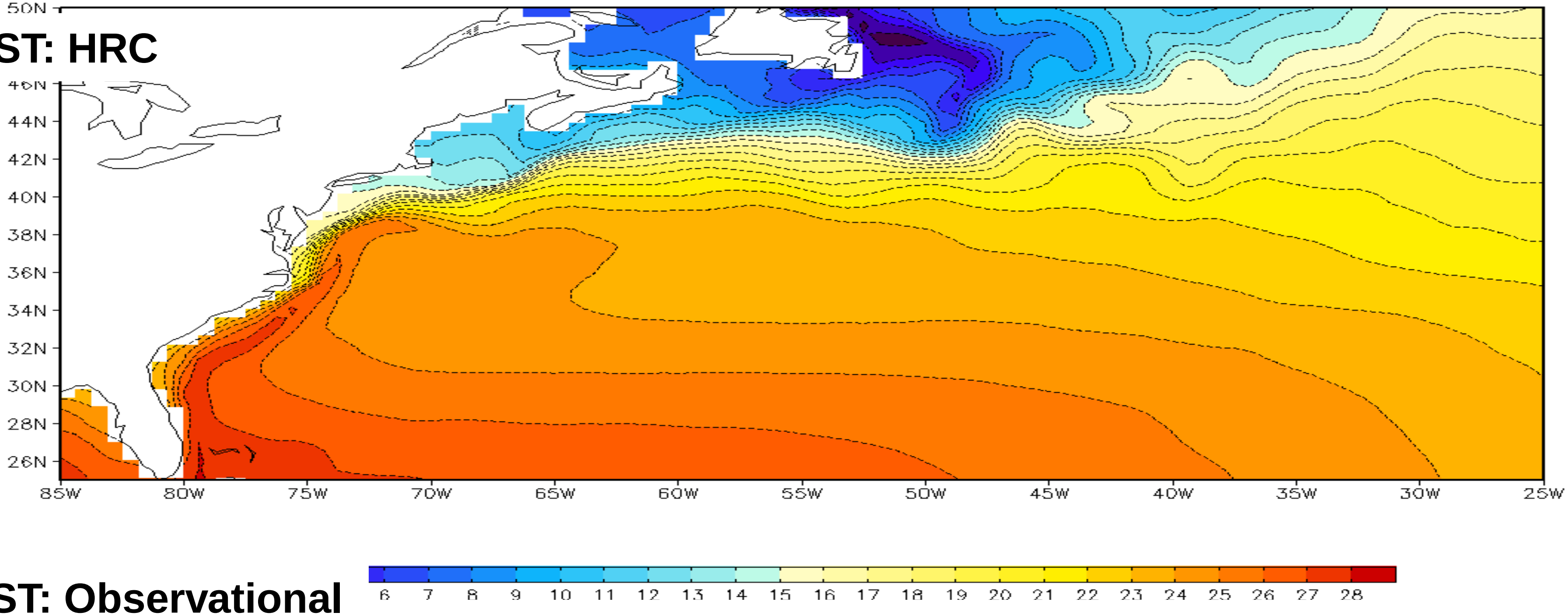
SST: LRC



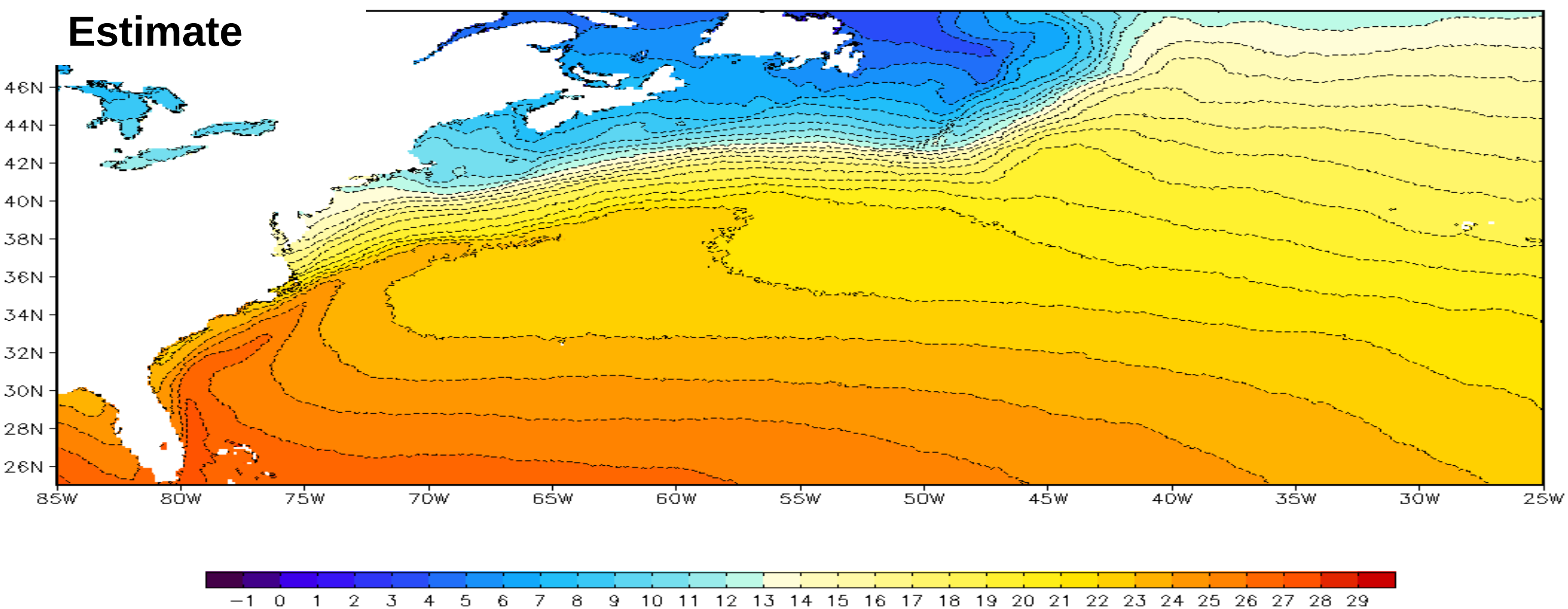
SST: Observational Estimate



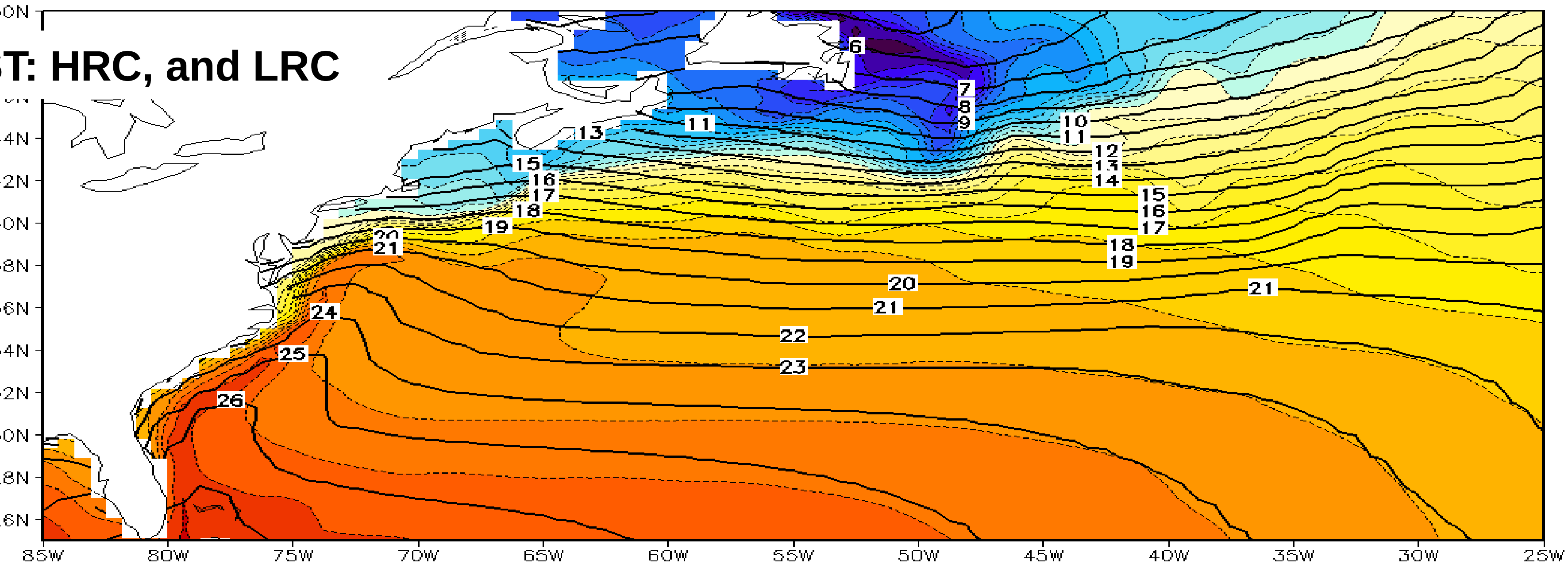
SST: HRC



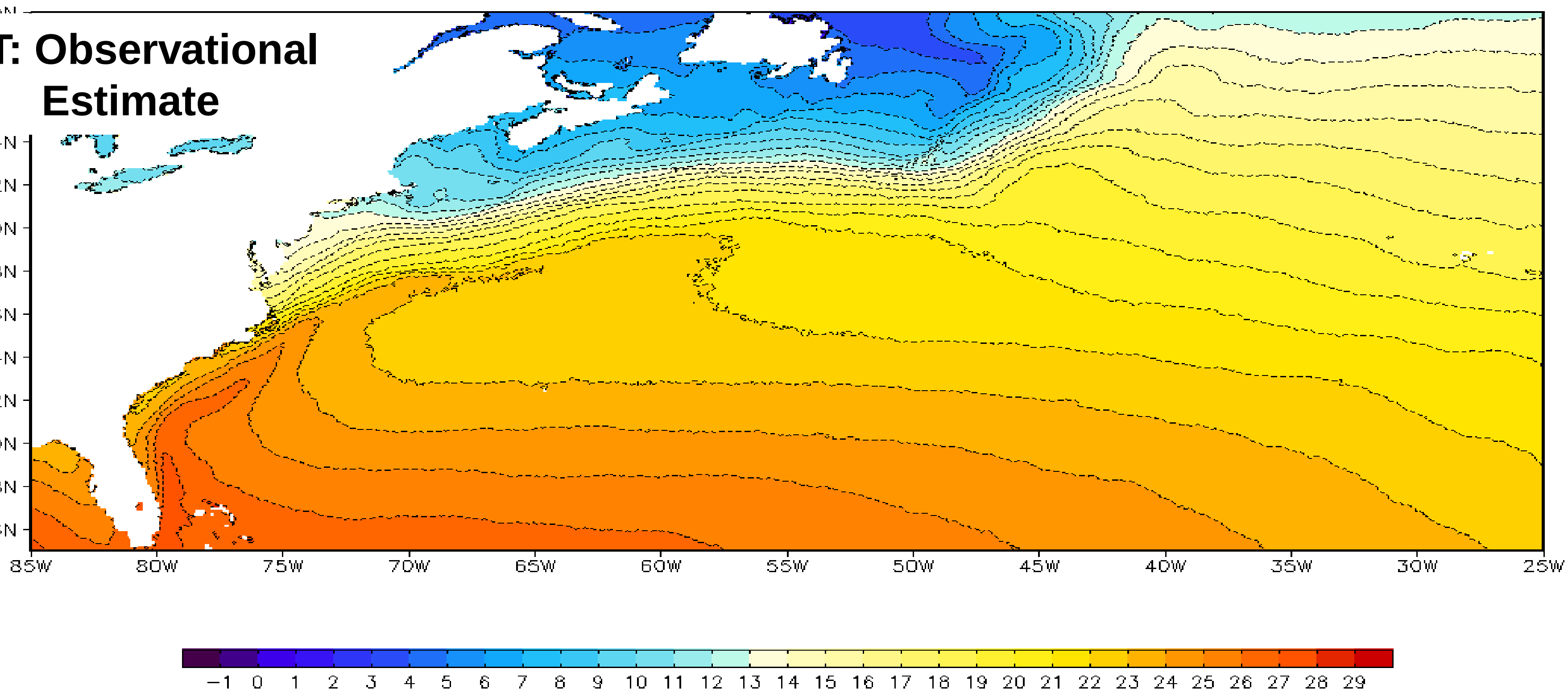
SST: Observational Estimate

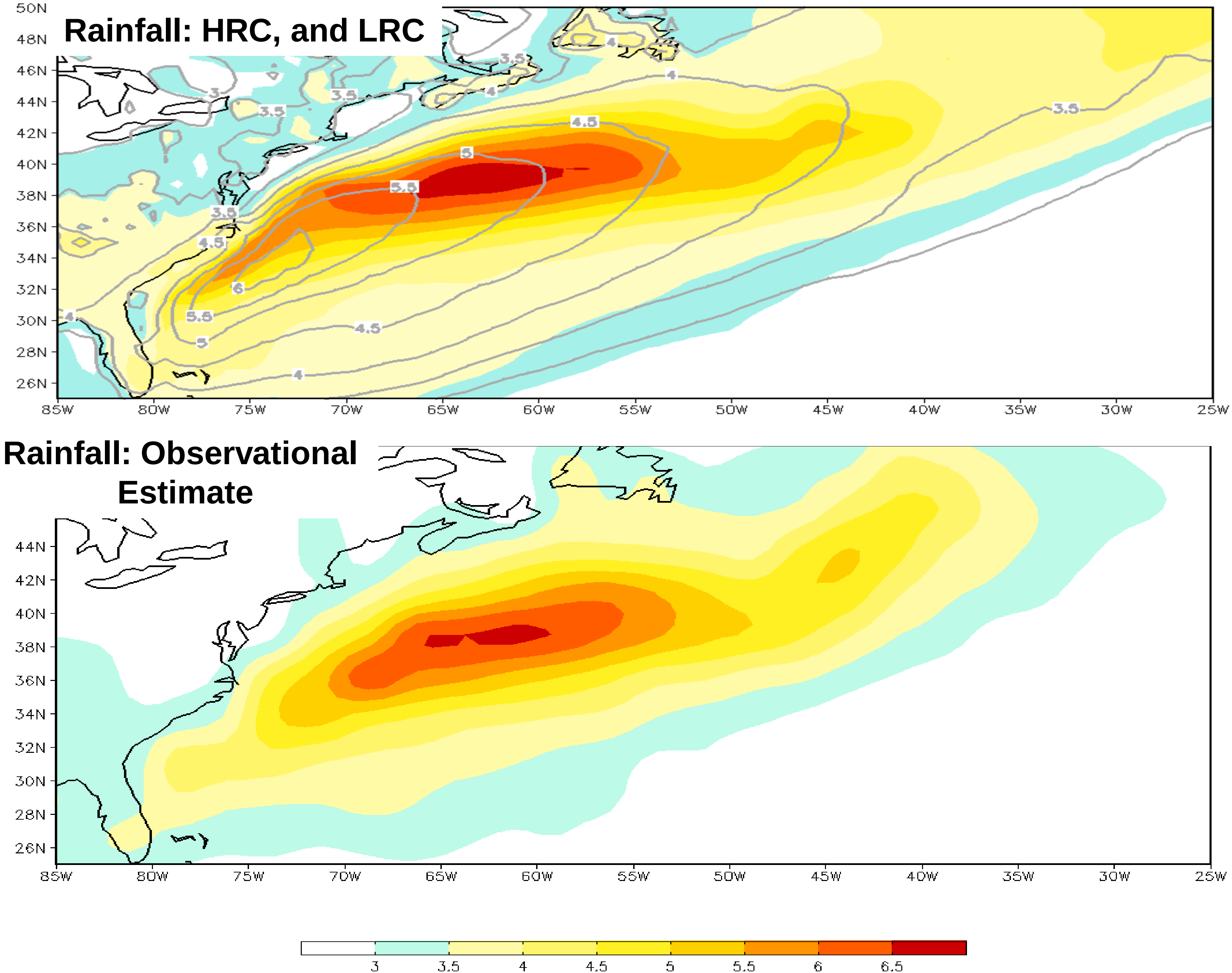


SST: HRC, and LRC

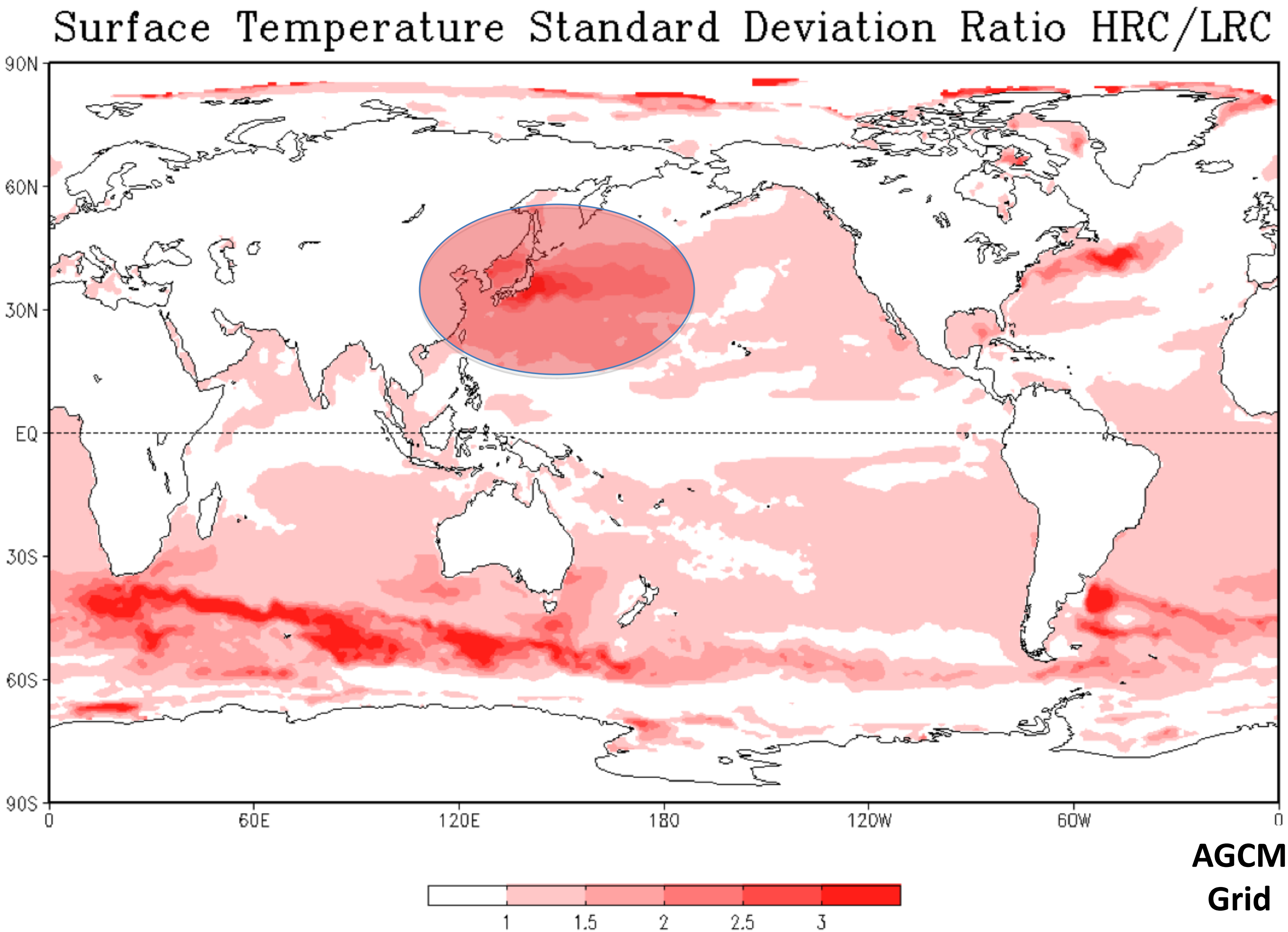


SST: Observational Estimate

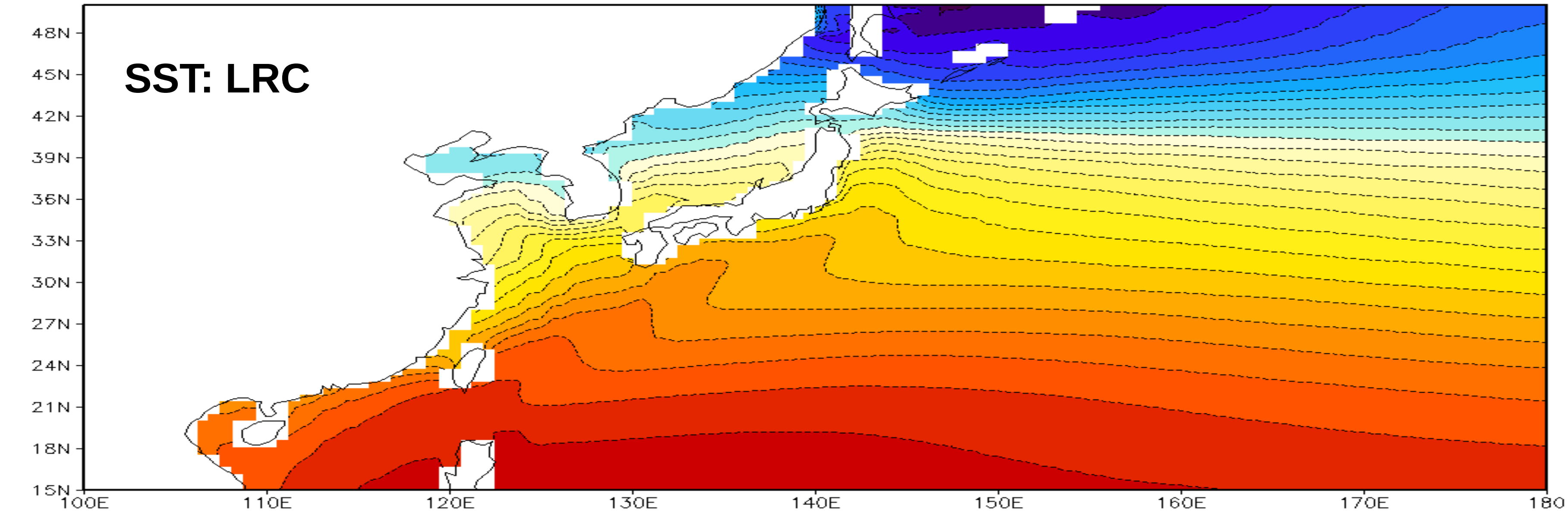




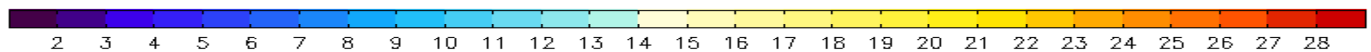
Rainfall: HRC, and LRC
50N
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
85W
80W
75W
70W
65W
60W
55W
50W
45W
40W
35W
30W
25W
Rainfall: Observational Estimate
3
3.5
4
4.5
5
5.5
6
6.5

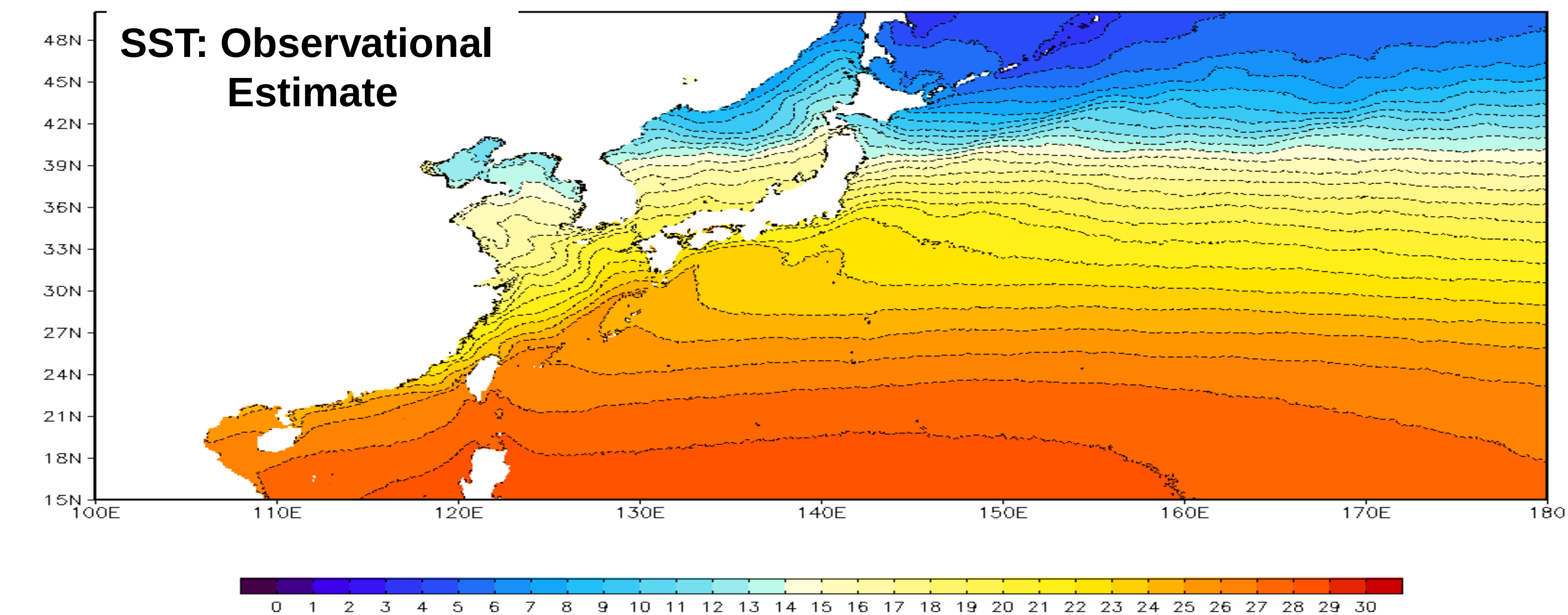


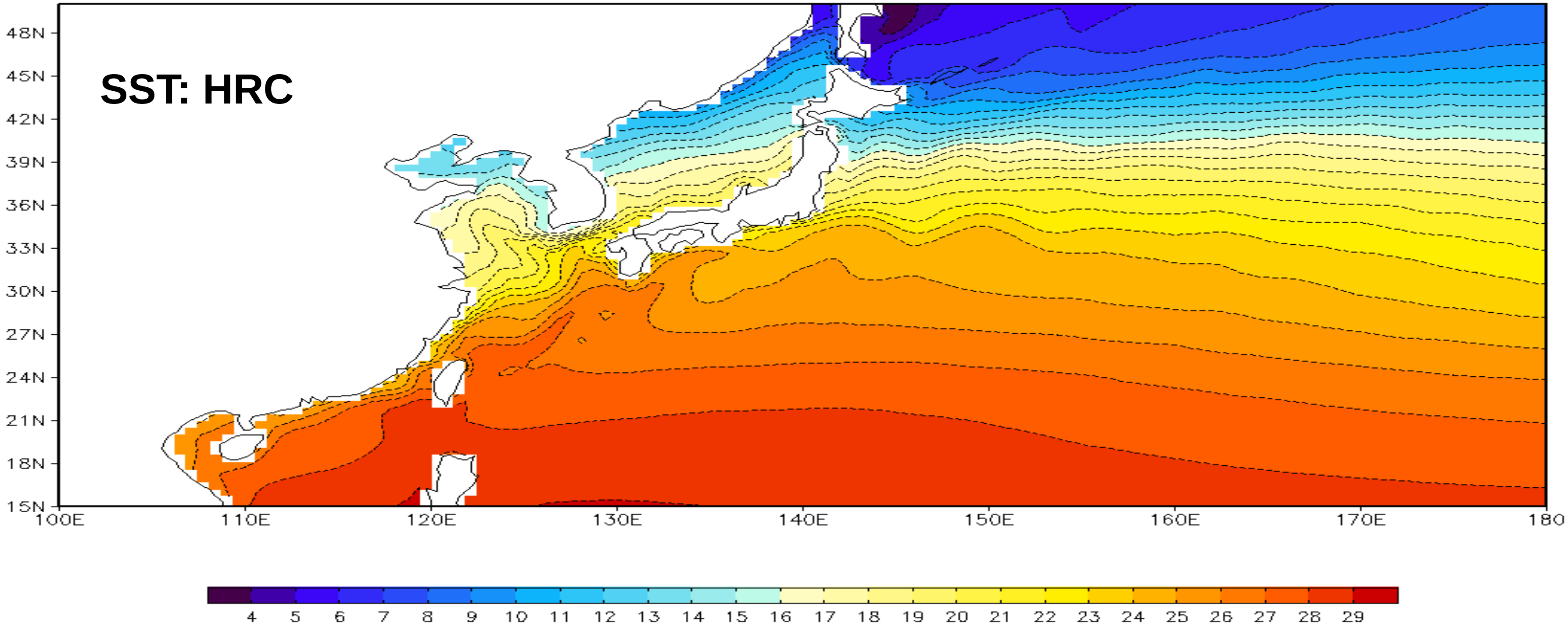
Surface Temperature Standard Deviation Ratio HRC/LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
1
1.5
2
2.5
3
AGCM
Grid

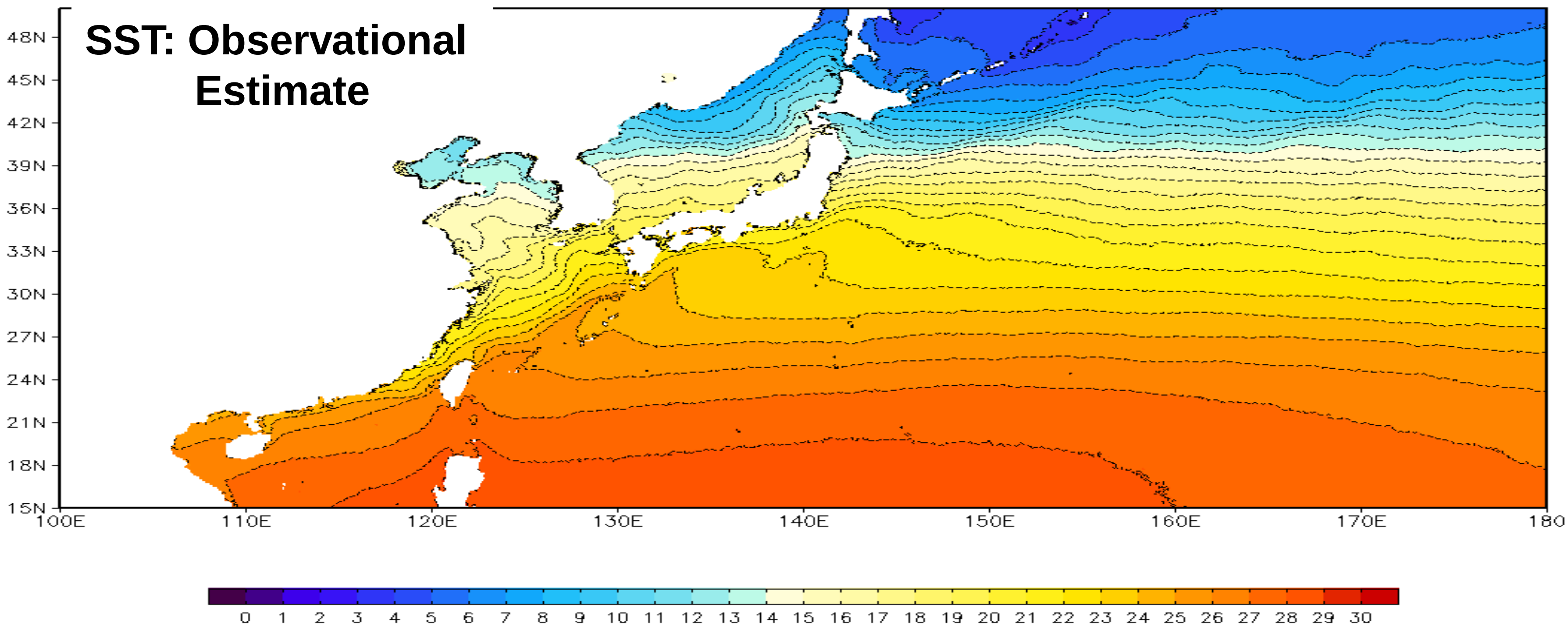


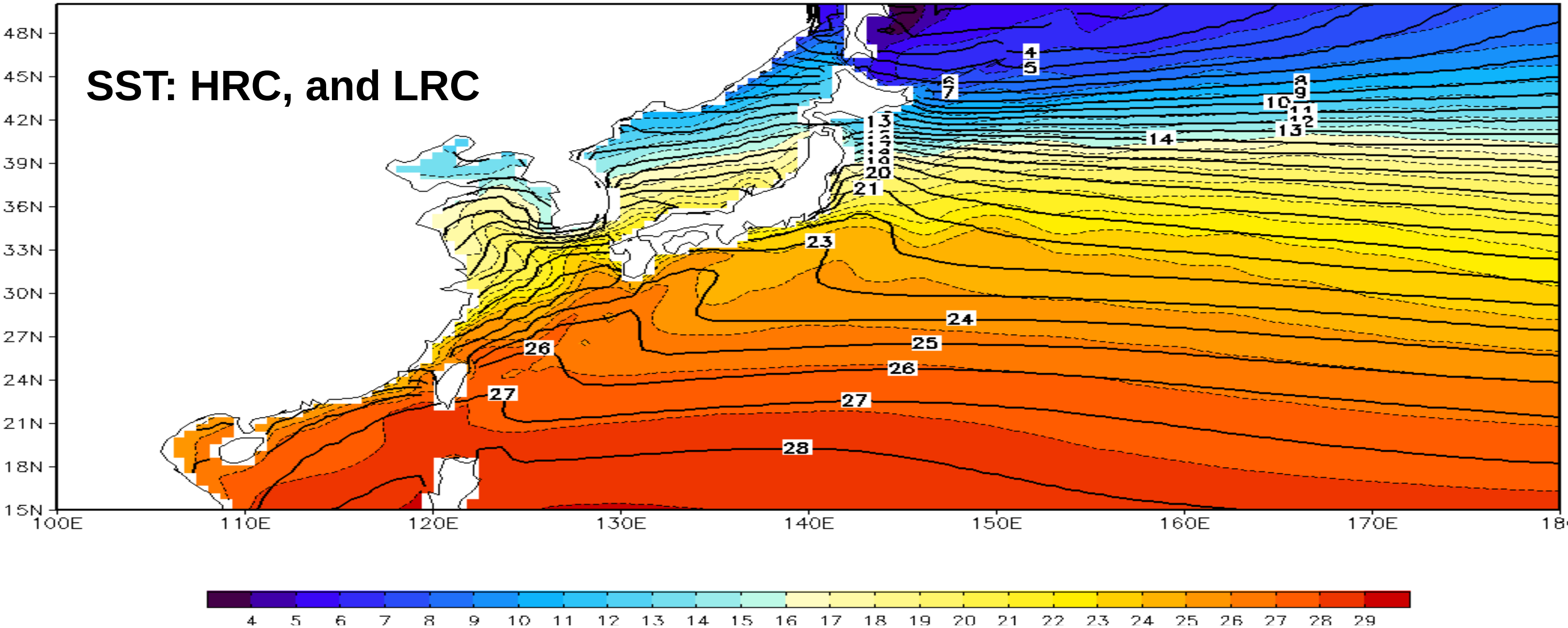
North Pacific SST

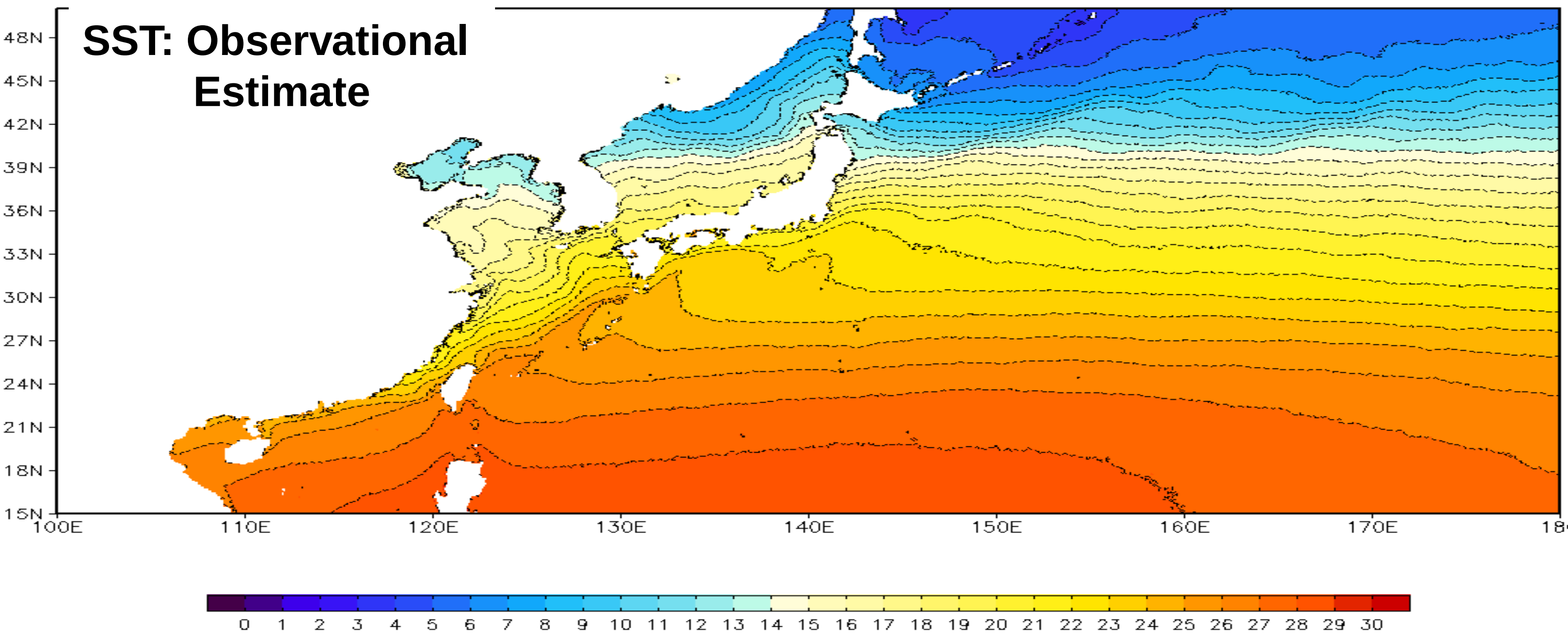


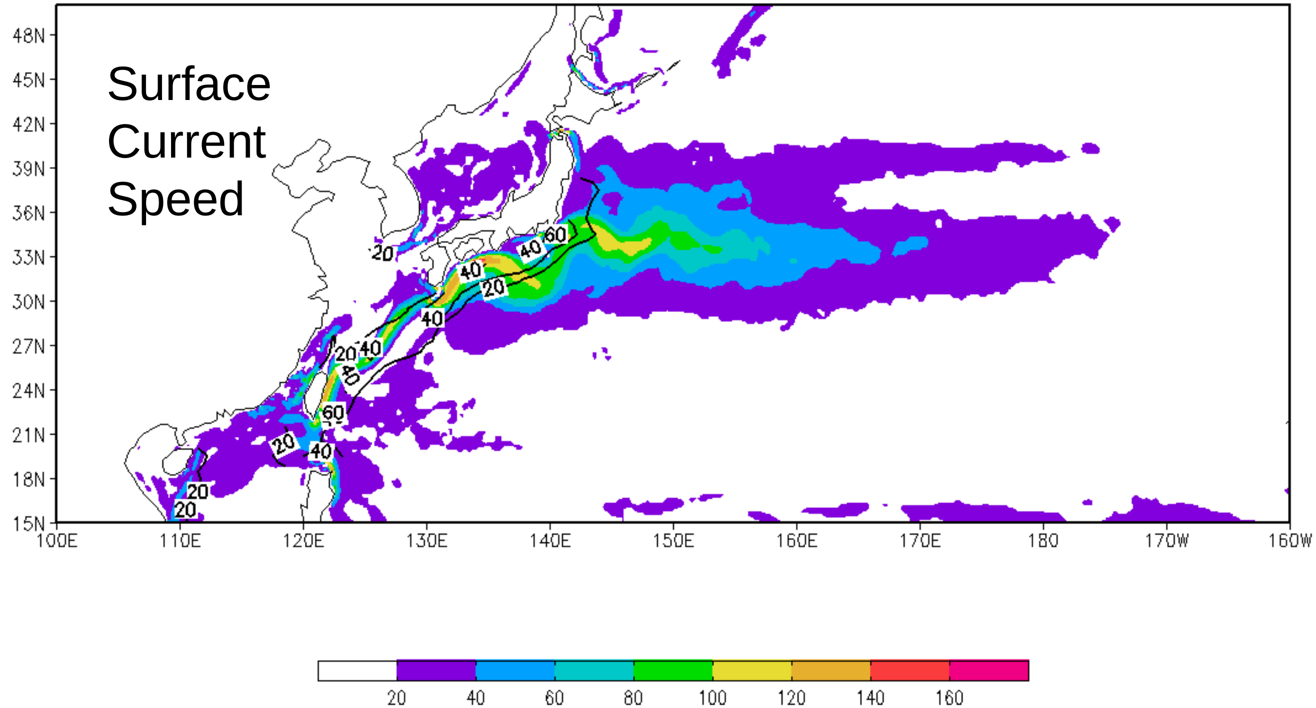



SST: HRC
48N
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15N
100E 110E 120E 130E 140E 150E 160E 170E 180
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

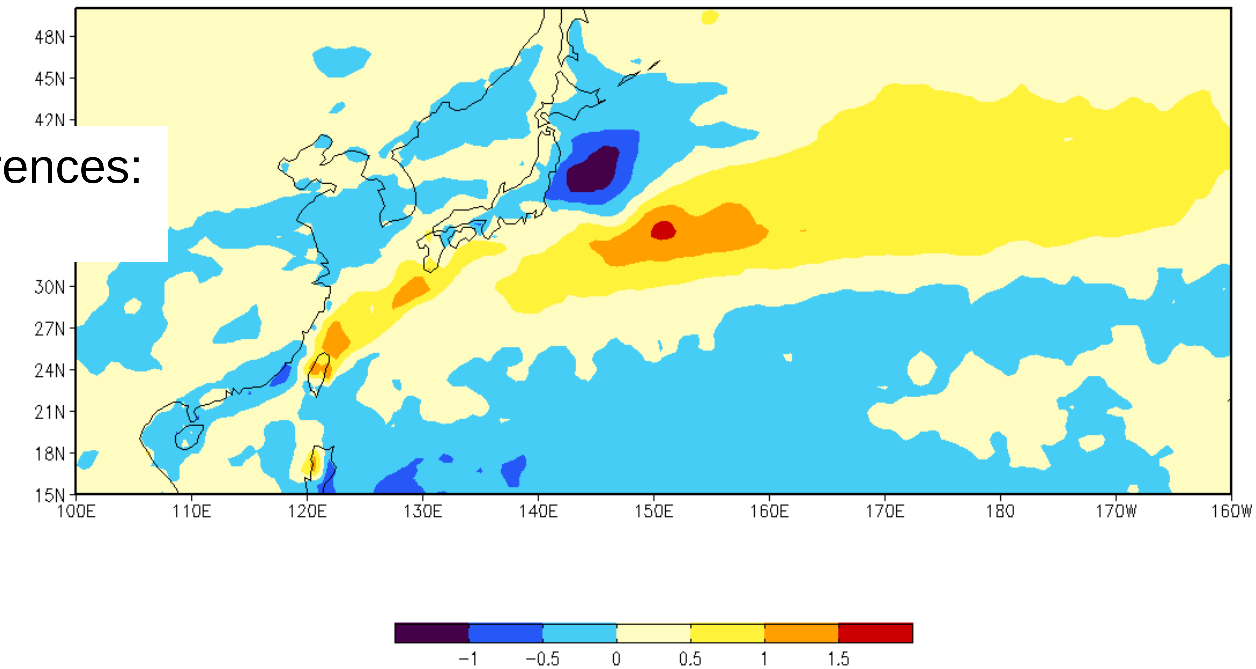

SST: Observational Estimate
48N
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15N
100E 110E 120E 130E 140E 150E 160E 170E 180
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

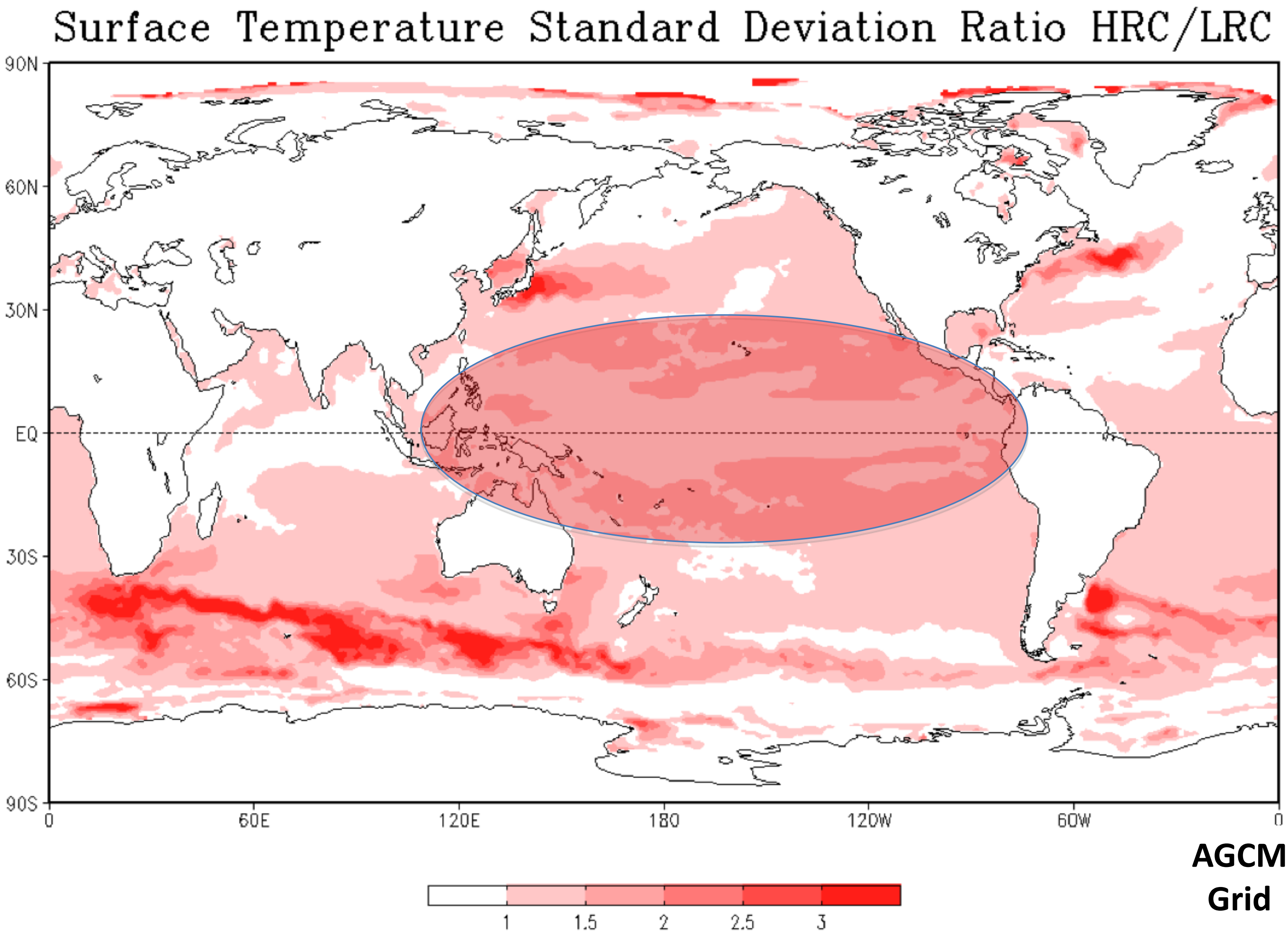

SST: HRC, and LRC
48N
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15N
100E
110E
120E
130E
140E
150E
160E
170E
180
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29


SST: Observational Estimate
48N
45N
42N
39N
36N
33N
30N
27N
24N
21N
18N
15N
100E
110E
120E
130E
140E
150E
160E
170E
180
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

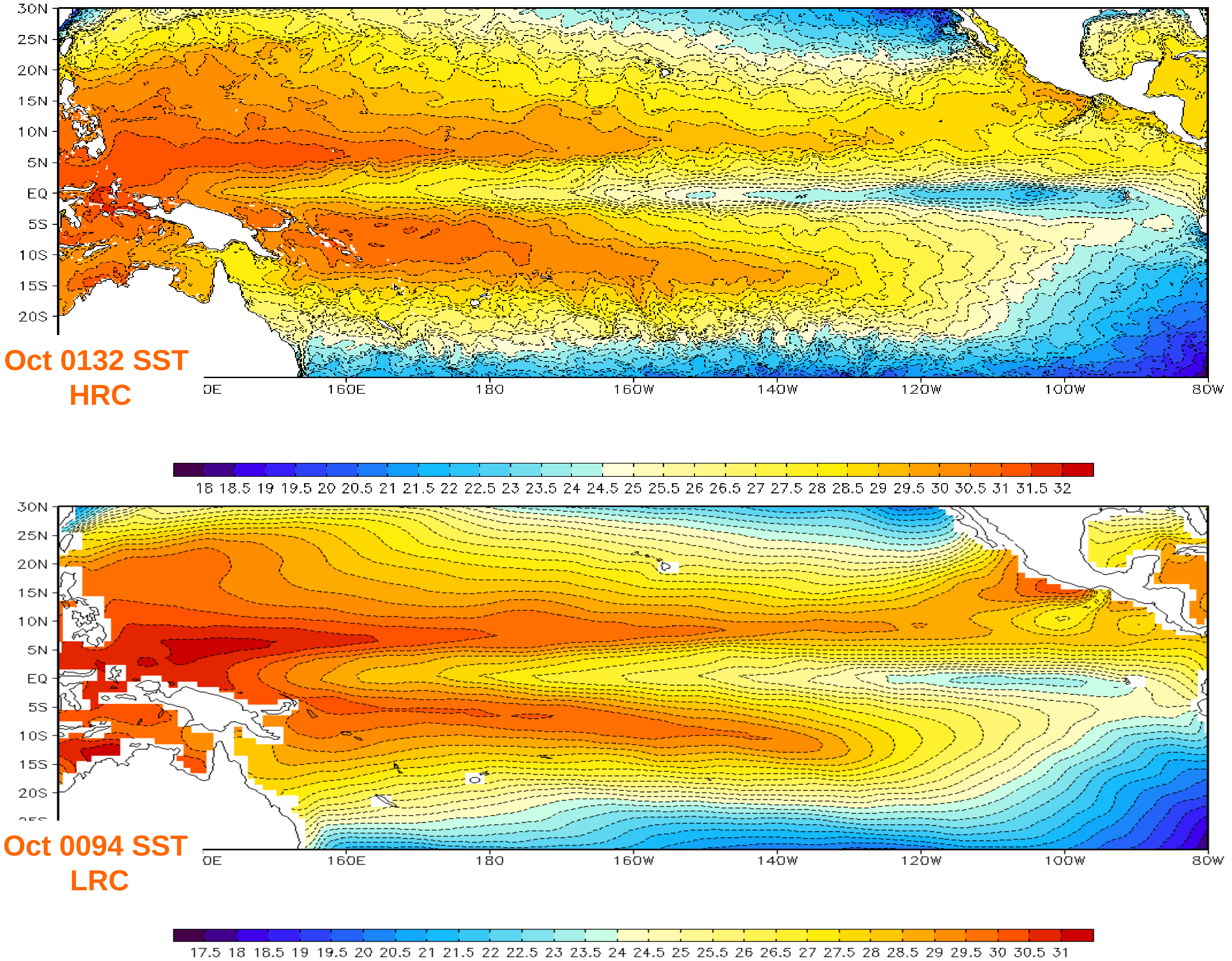


Rainfall Differences:
HRC-LRC

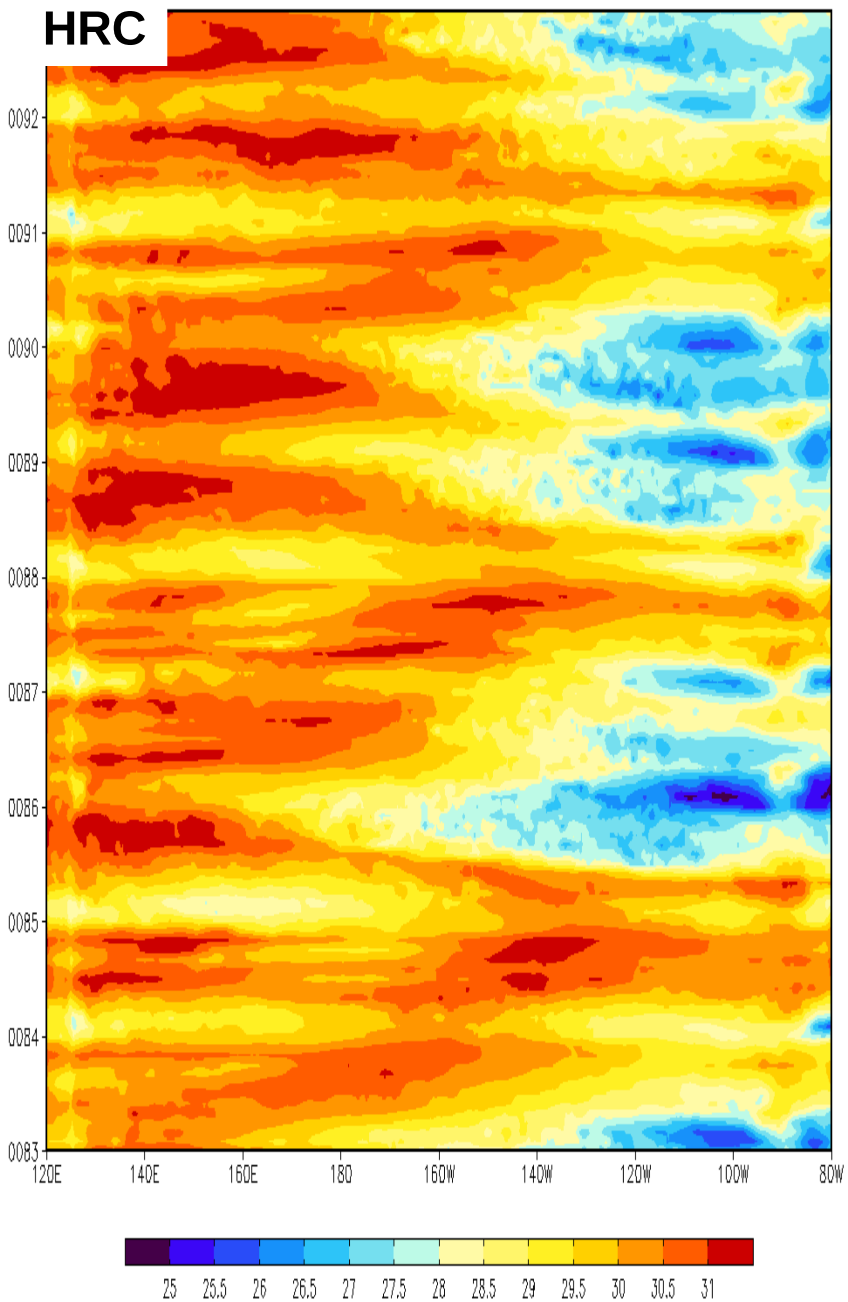


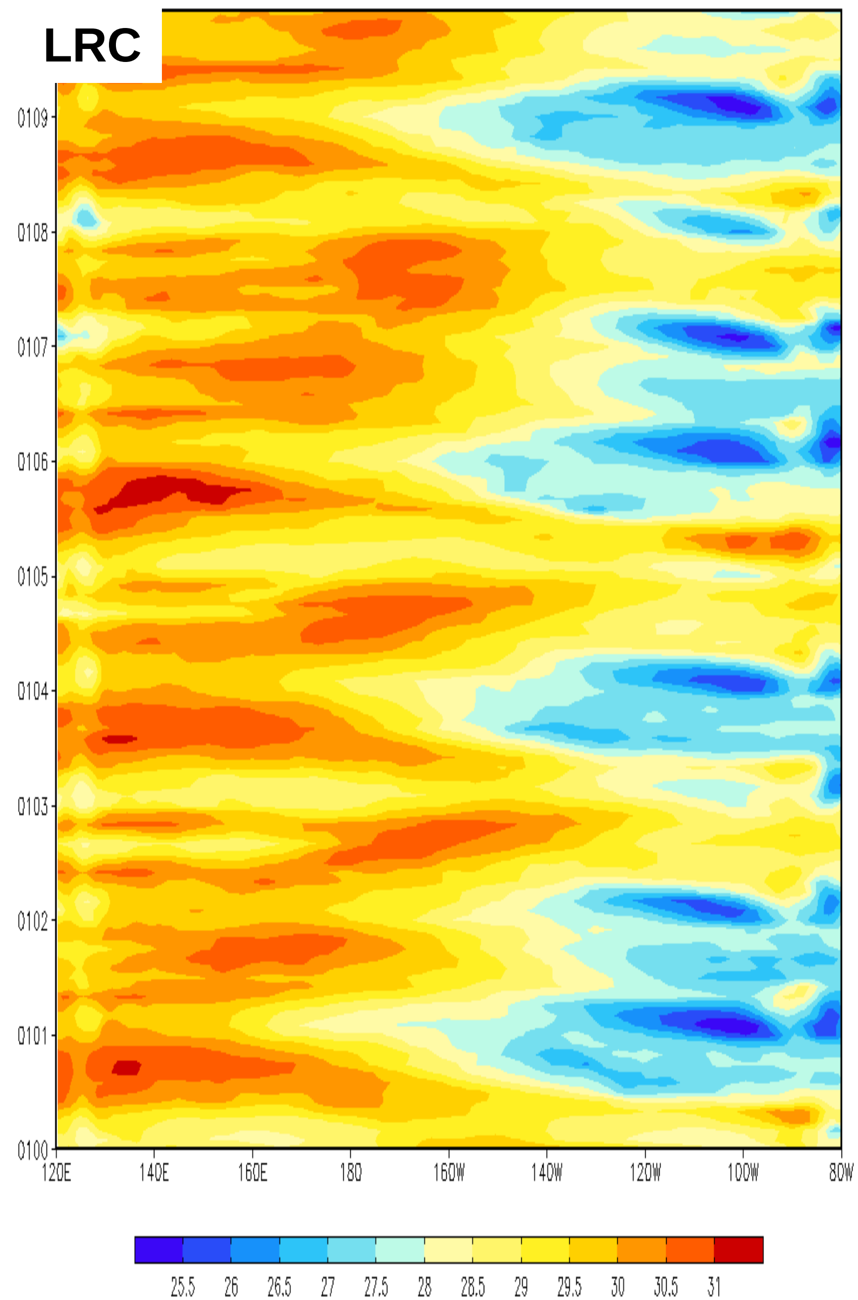


Surface Temperature Standard Deviation Ratio HRC/LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
1
1.5
2
2.5
3
AGCM
Grid

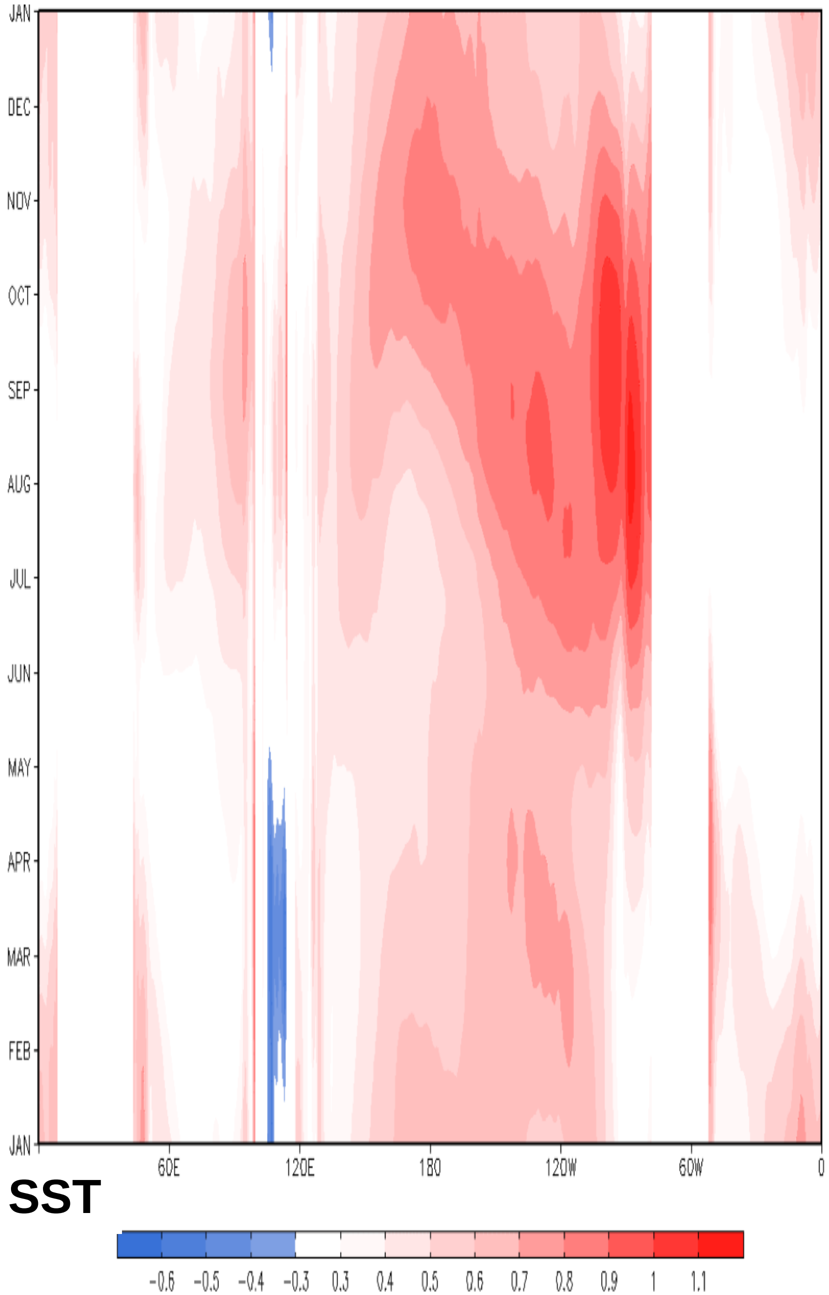

Oct 0132 SST
HRC
30N 25N 20N 15N 10N 5N EQ 5S 10S 15S 20S
0E 160E 180 160W 140W 120W 100W 80W
18 18.5 19 19.5 20 20.5 21 21.5 22 22.5 23 23.5 24 24.5 25 25.5 26 26.5 27 27.5 28 28.5 29 29.5 30 30.5 31 31.5 32
Oct 0094 SST
LRC
30N 25N 20N 15N 10N 5N EQ 5S 10S 15S 20S
0E 160E 180 160W 140W 120W 100W 80W
17.5 18 18.5 19 19.5 20 20.5 21 21.5 22 22.5 23 23.5 24 24.5 25 25.5 26 26.5 27 27.5 28 28.5 29 29.5 30 30.5 31

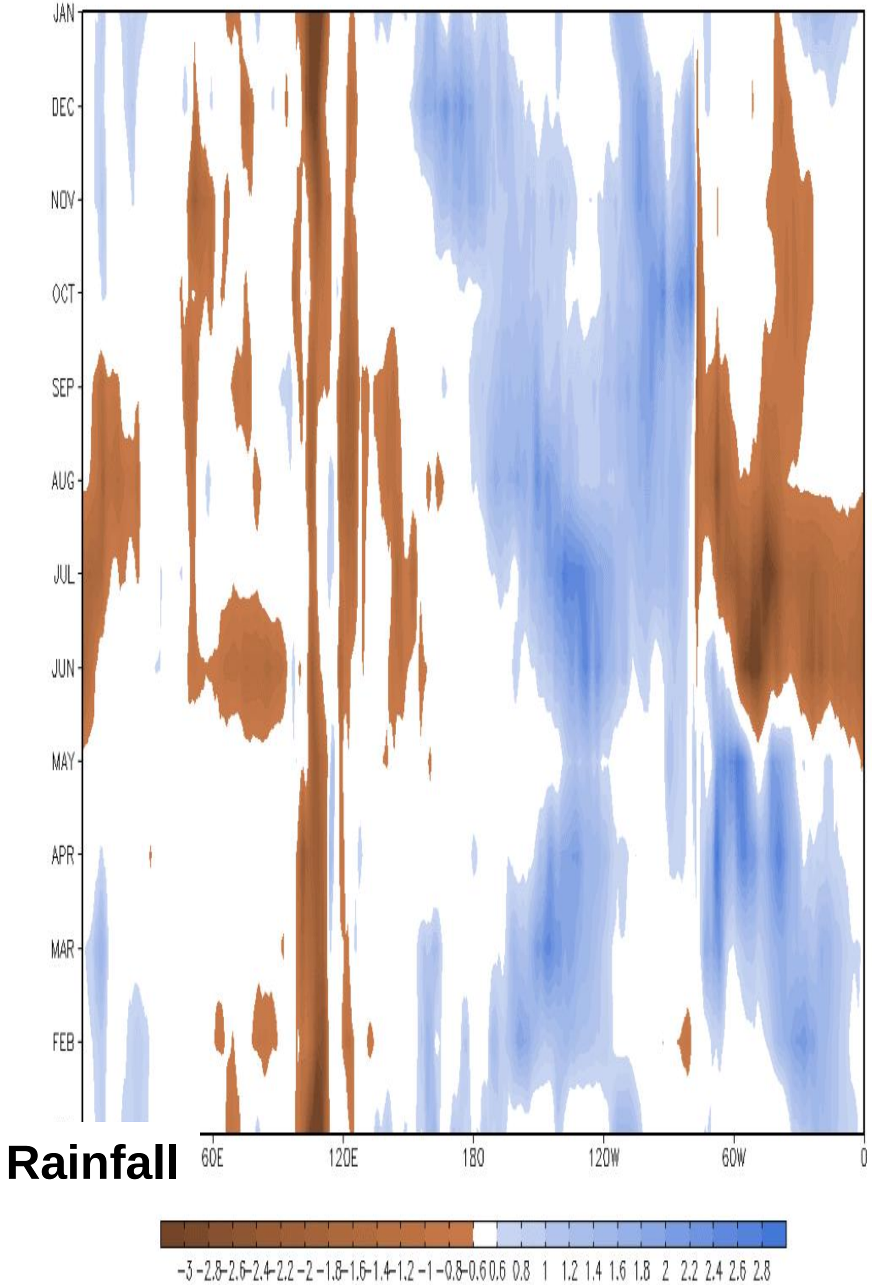
North Equatorial SSTs



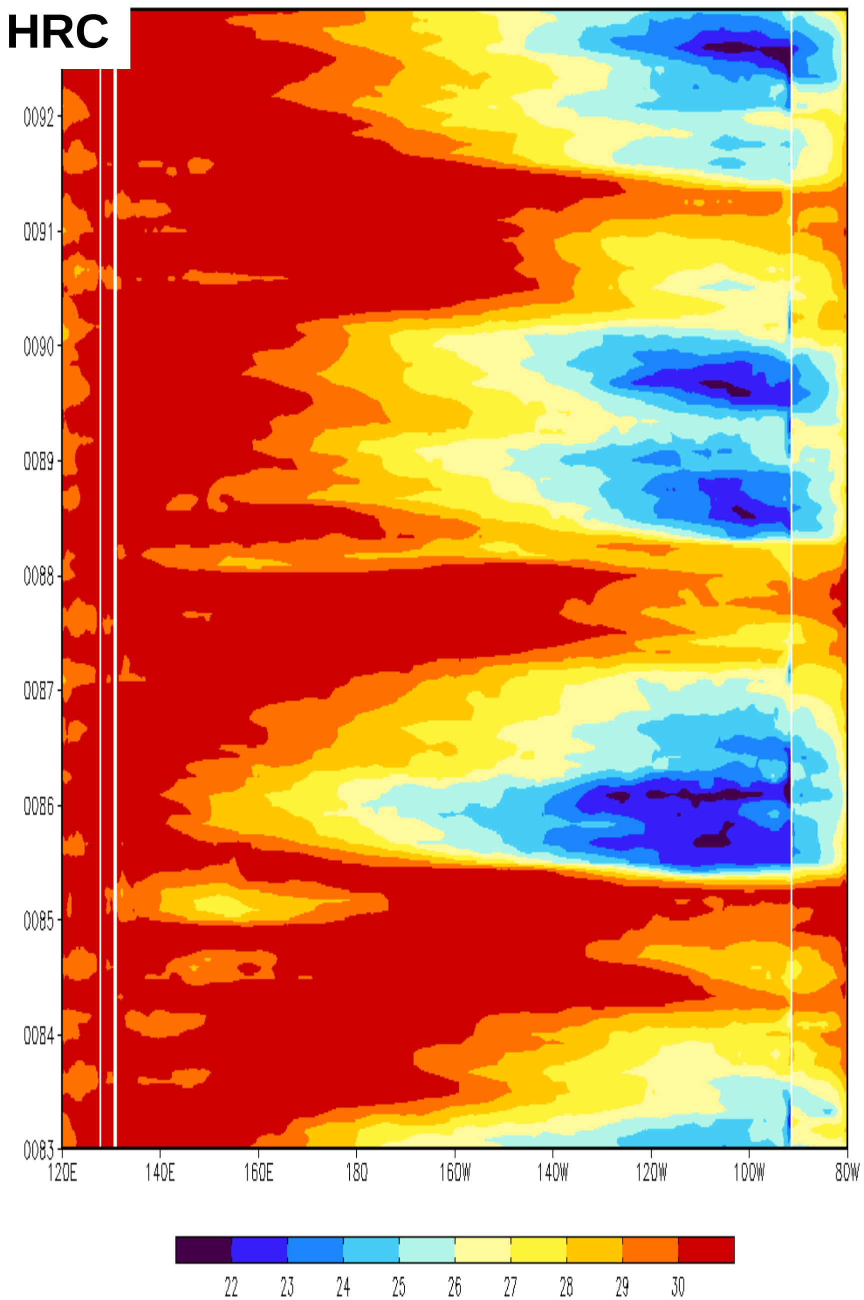


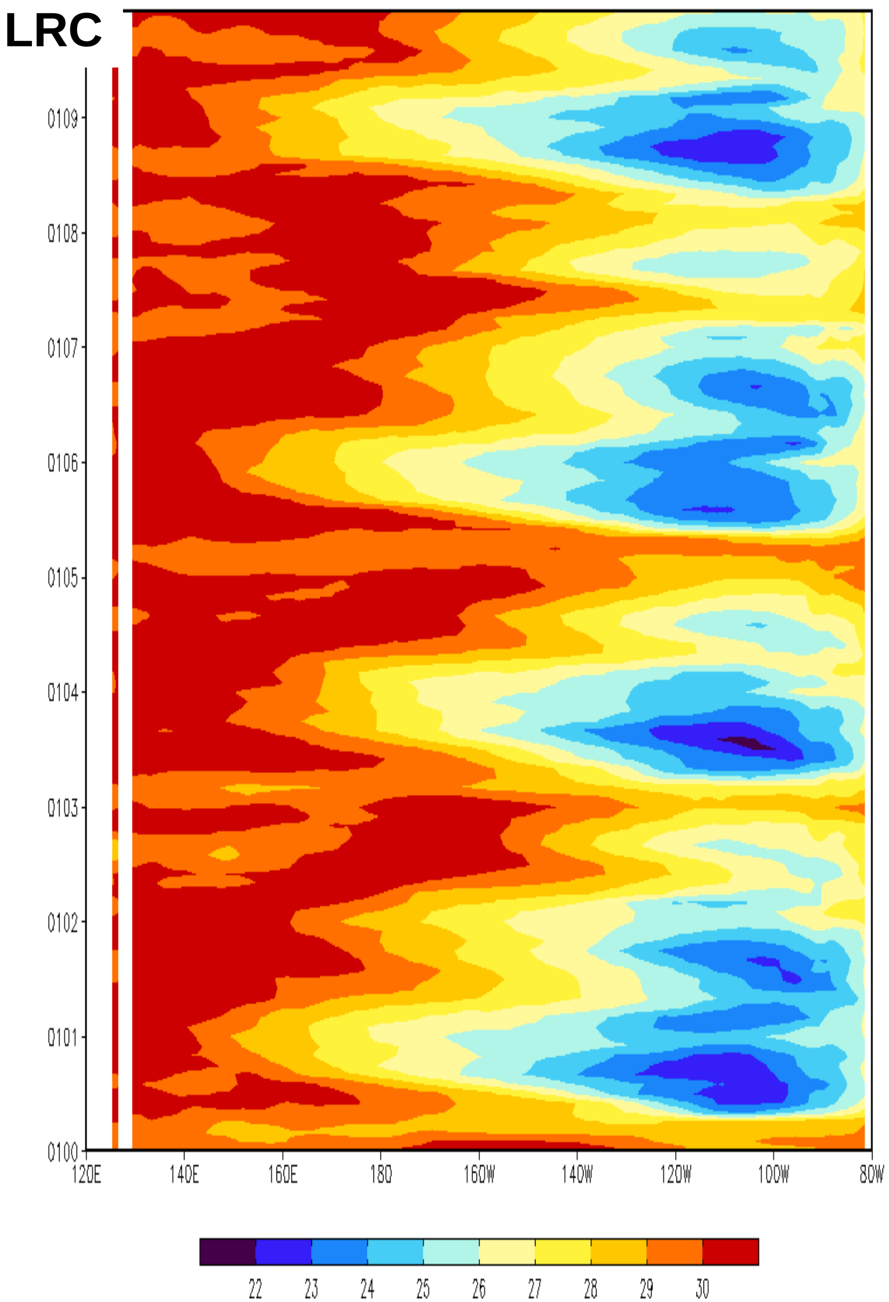
Changes in the 0-5N Annual Cycle



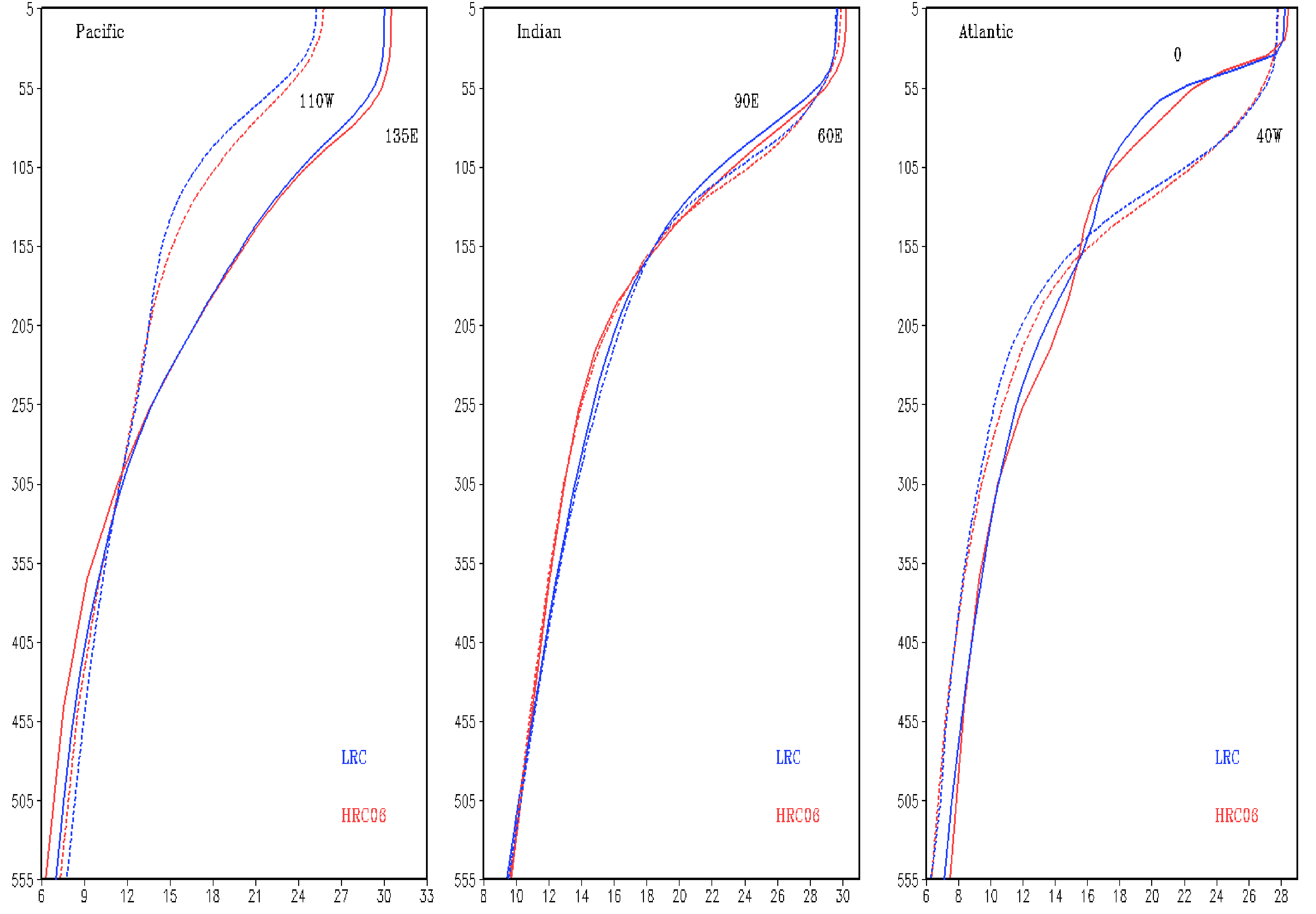


Equatorial SSTs



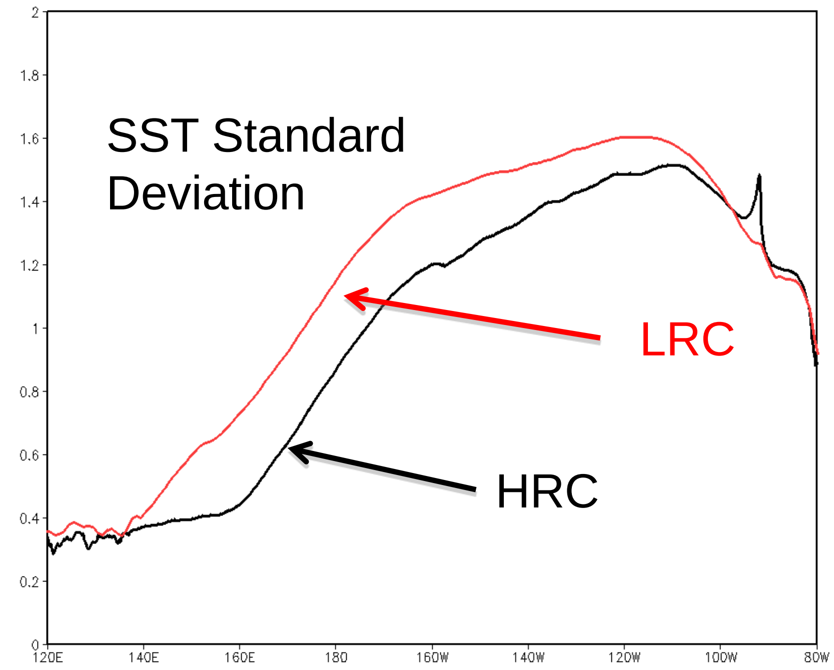


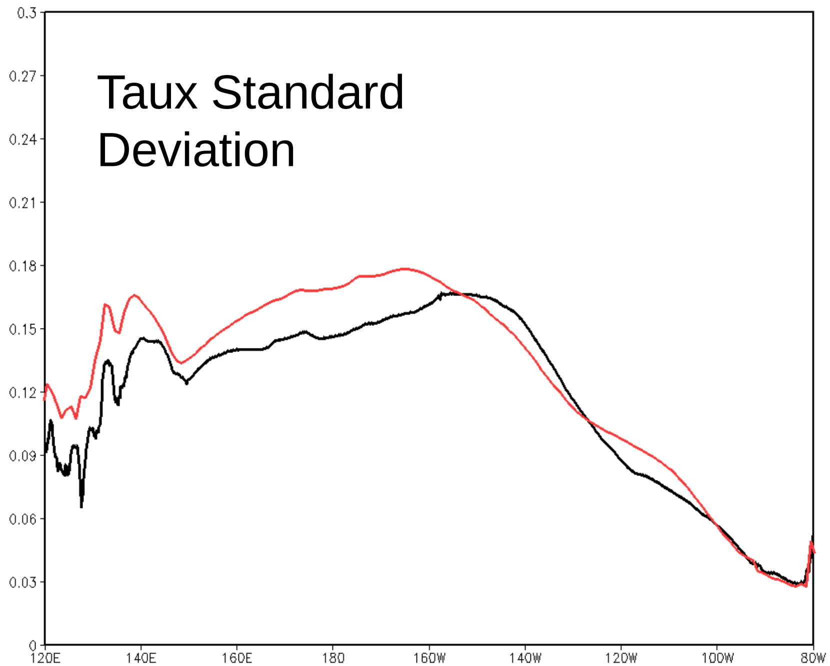
Equatorial Temperature Sections

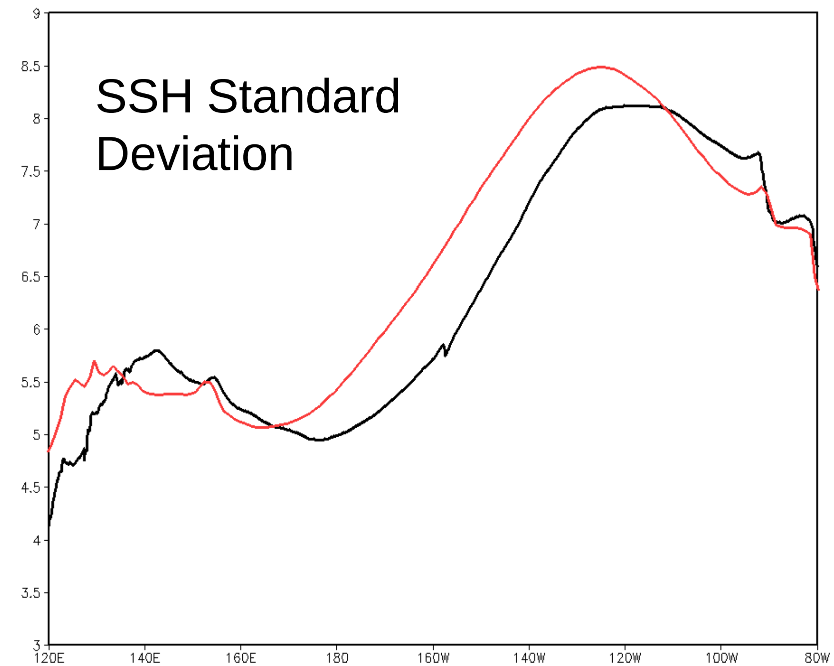


Equatorial Pacific Variability Statistics

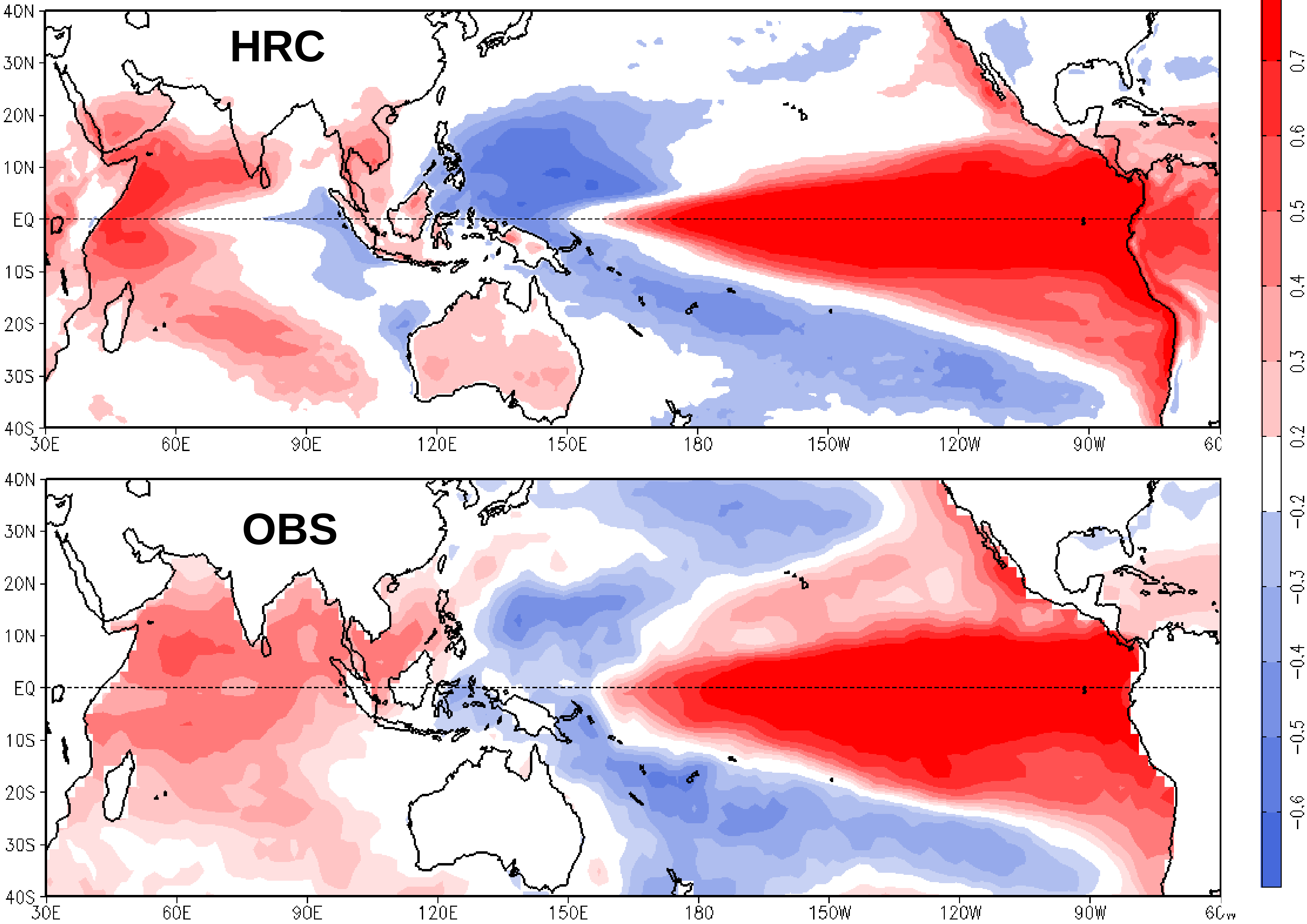
- **Reduced Variance with HRC**
- **Eastward Shift in Variability**
- **Affects Global Teleconnections**



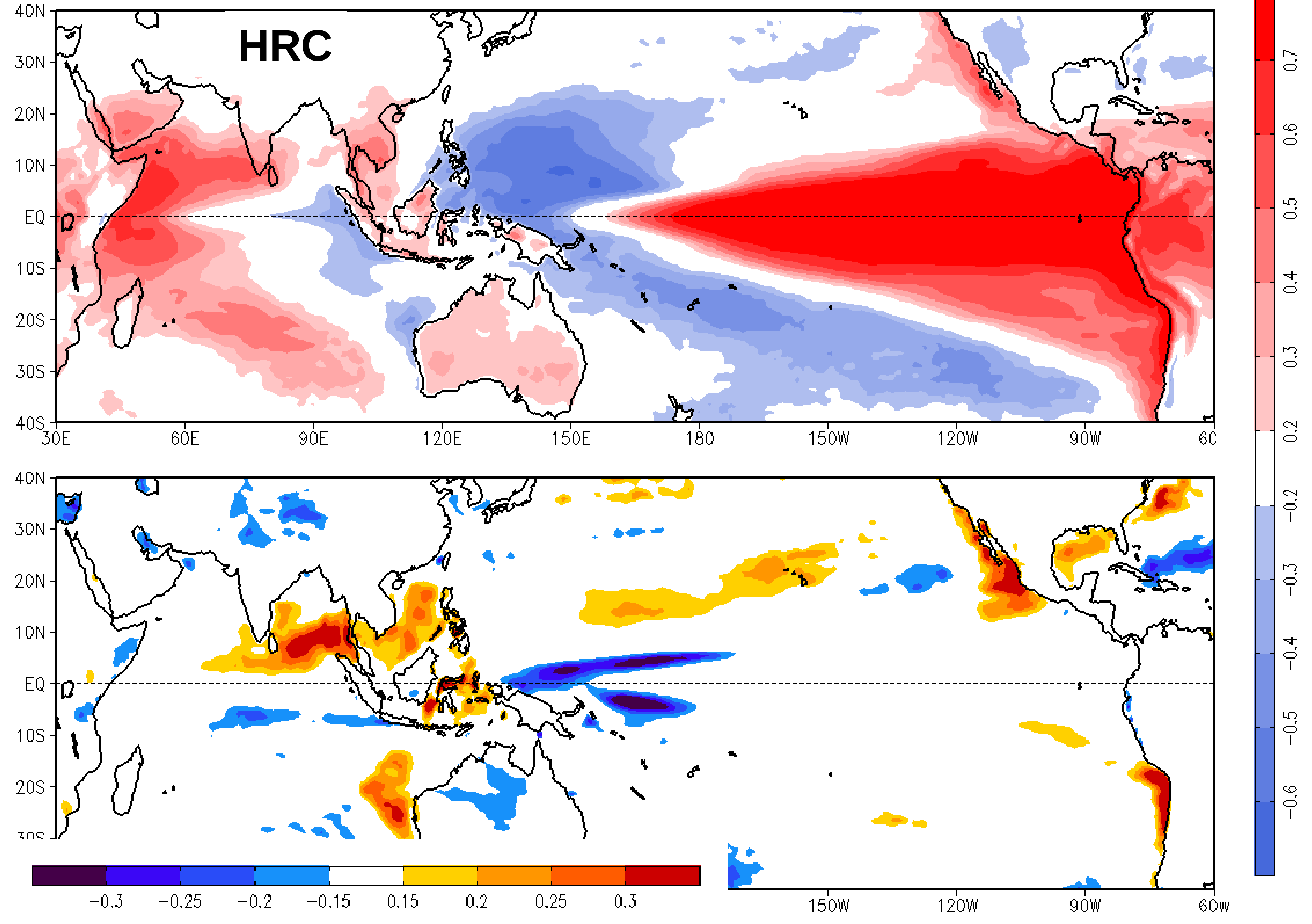




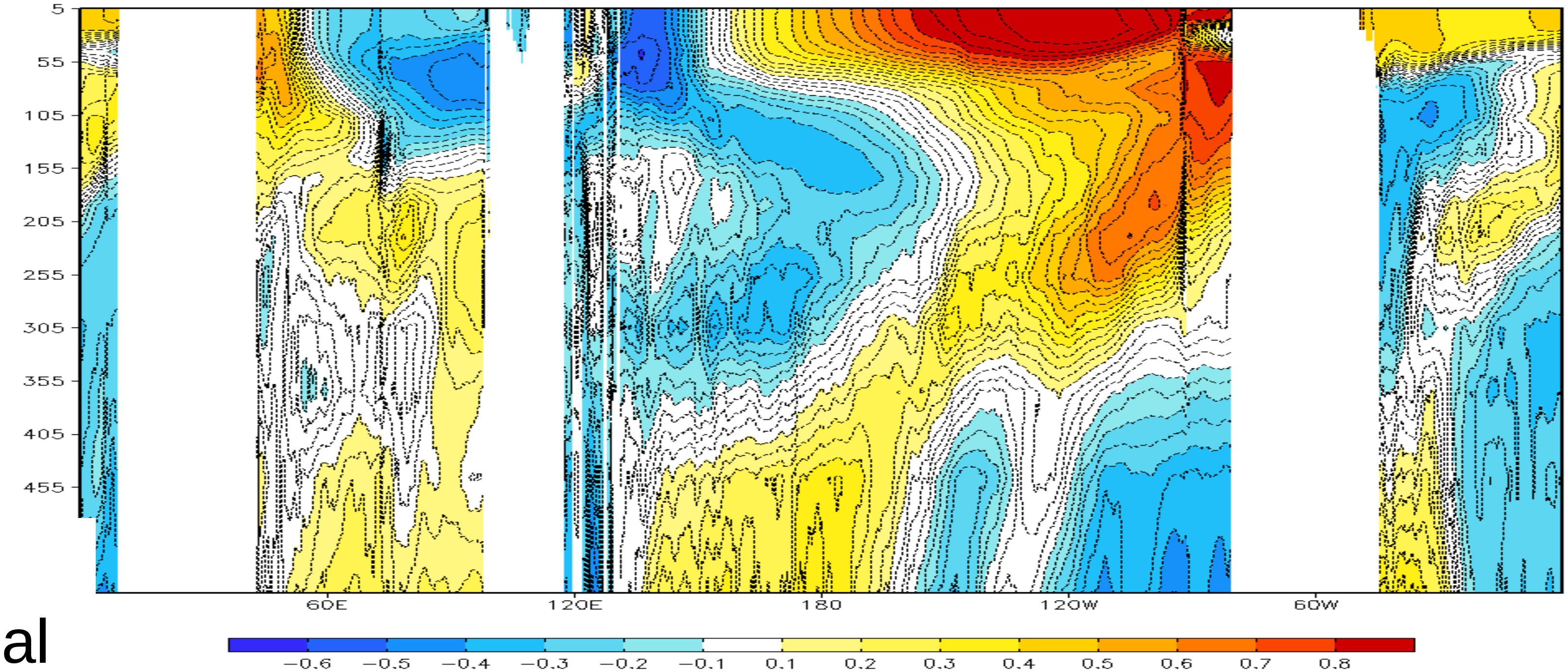
NINO34-SSTA Point Correlation



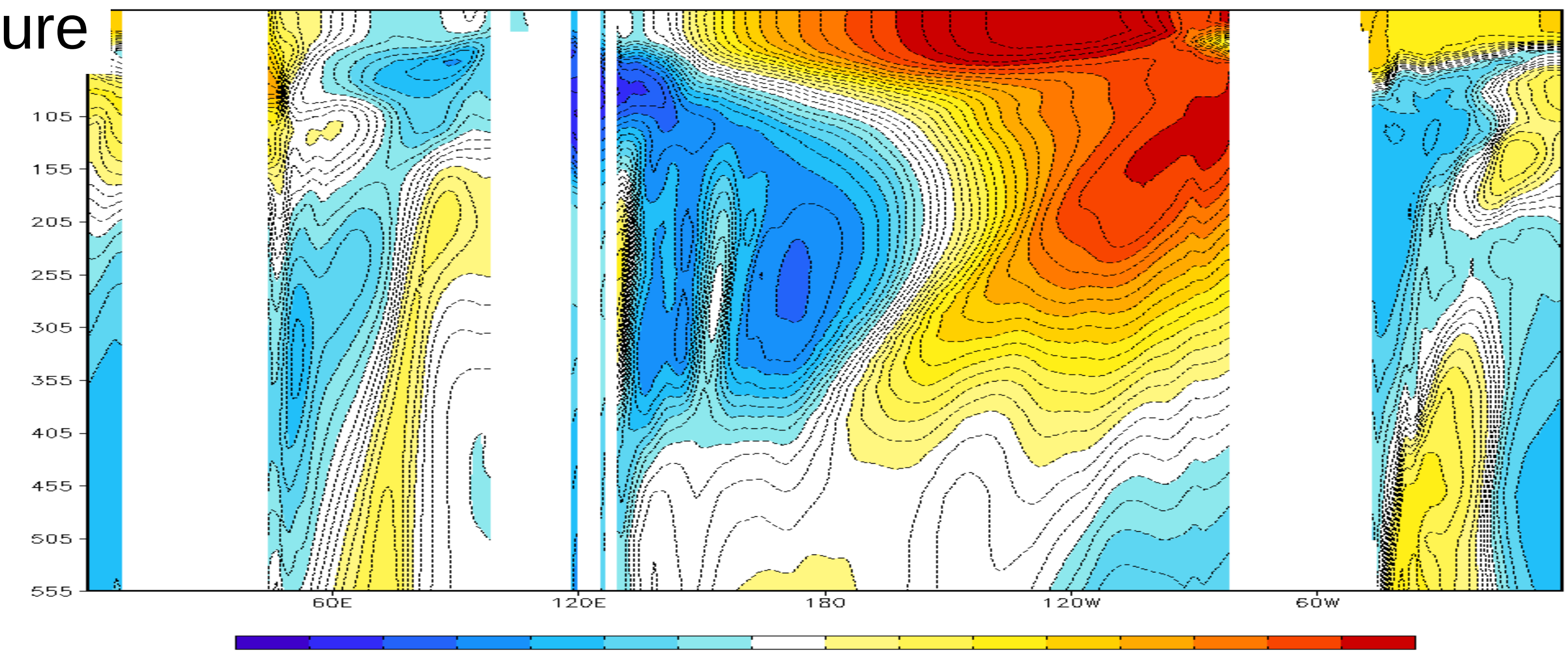
NINO34-SSTA Point Correlation



HRC

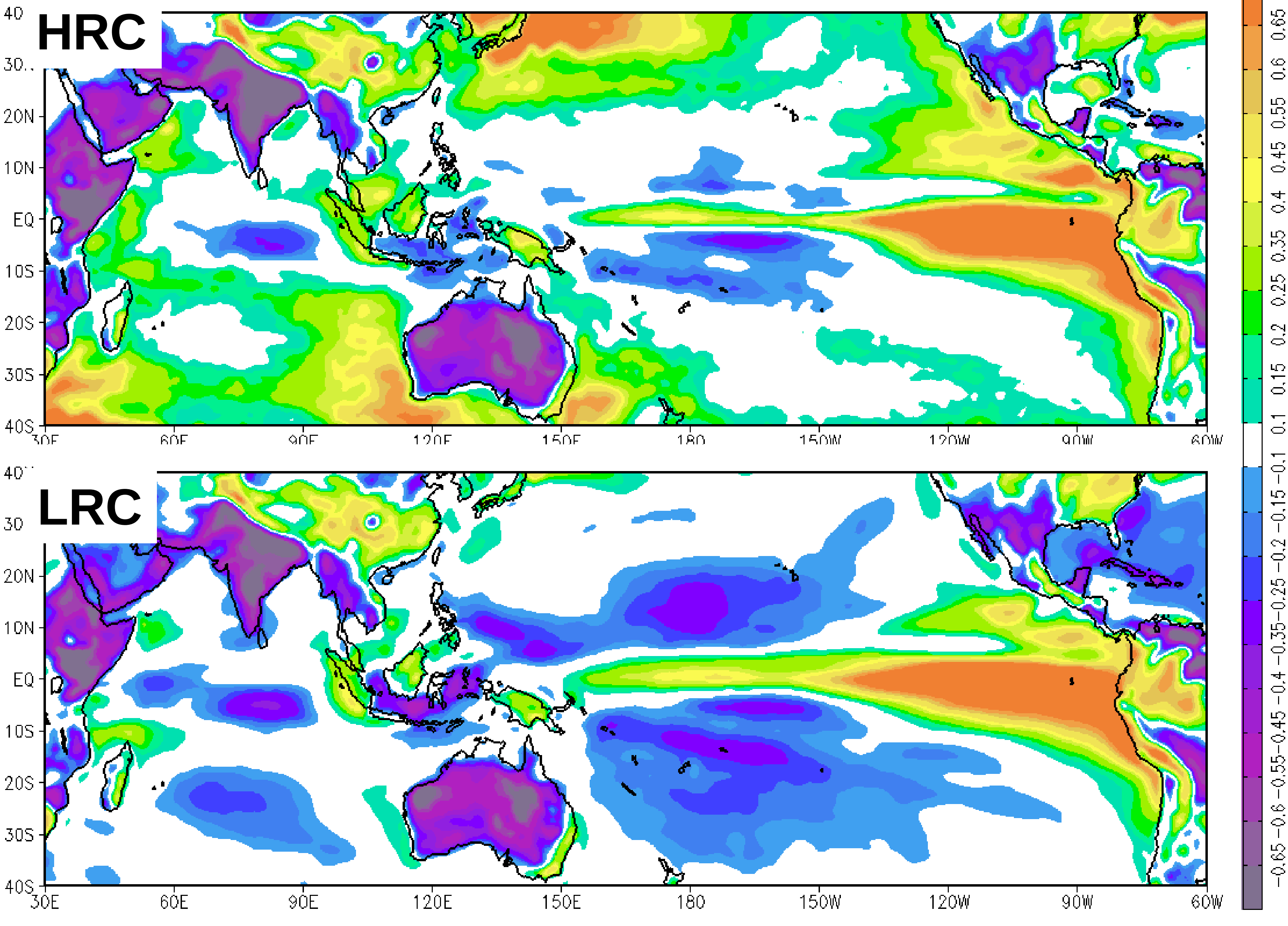


ENSO Thermal Structure

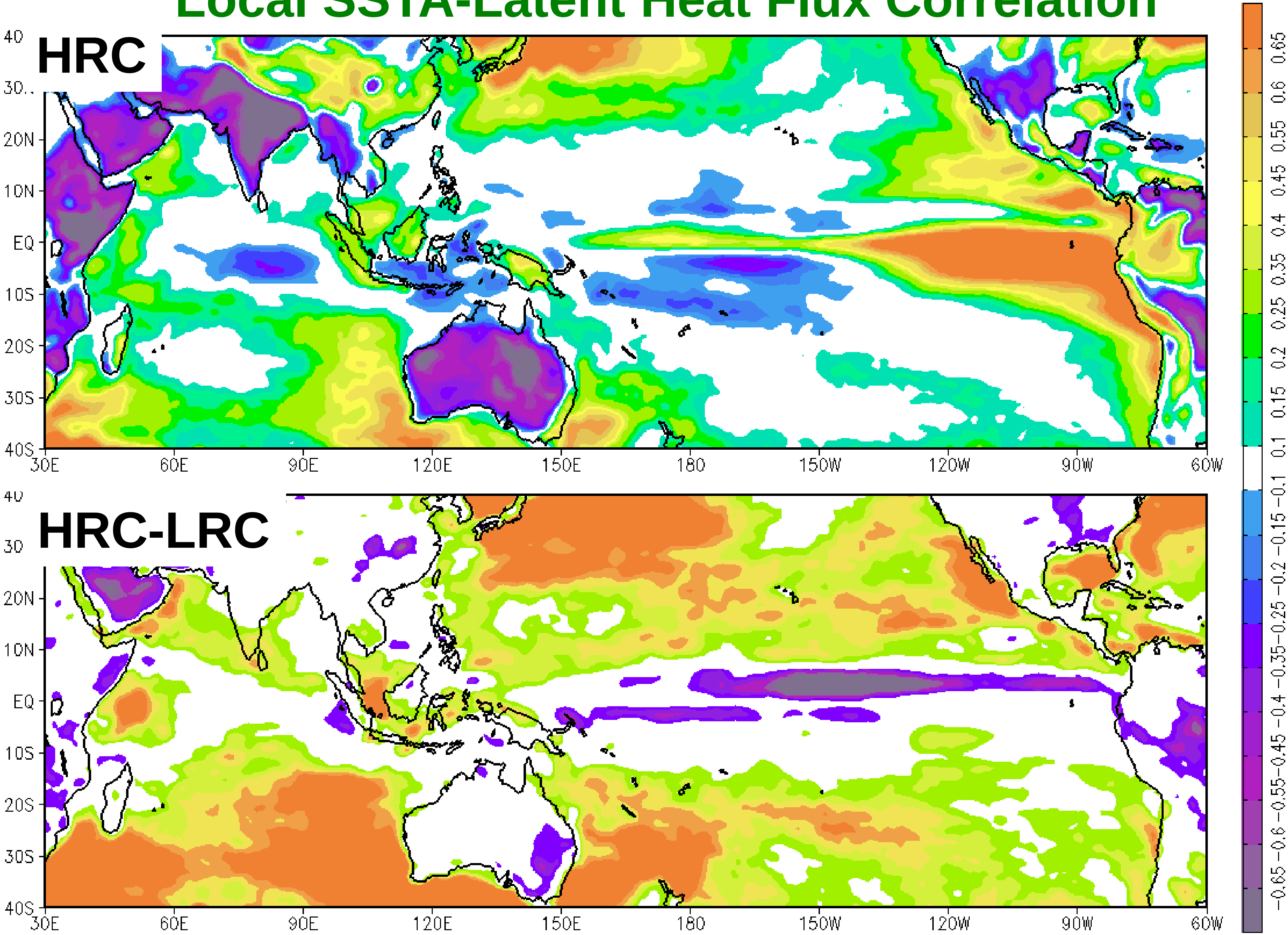


LRC

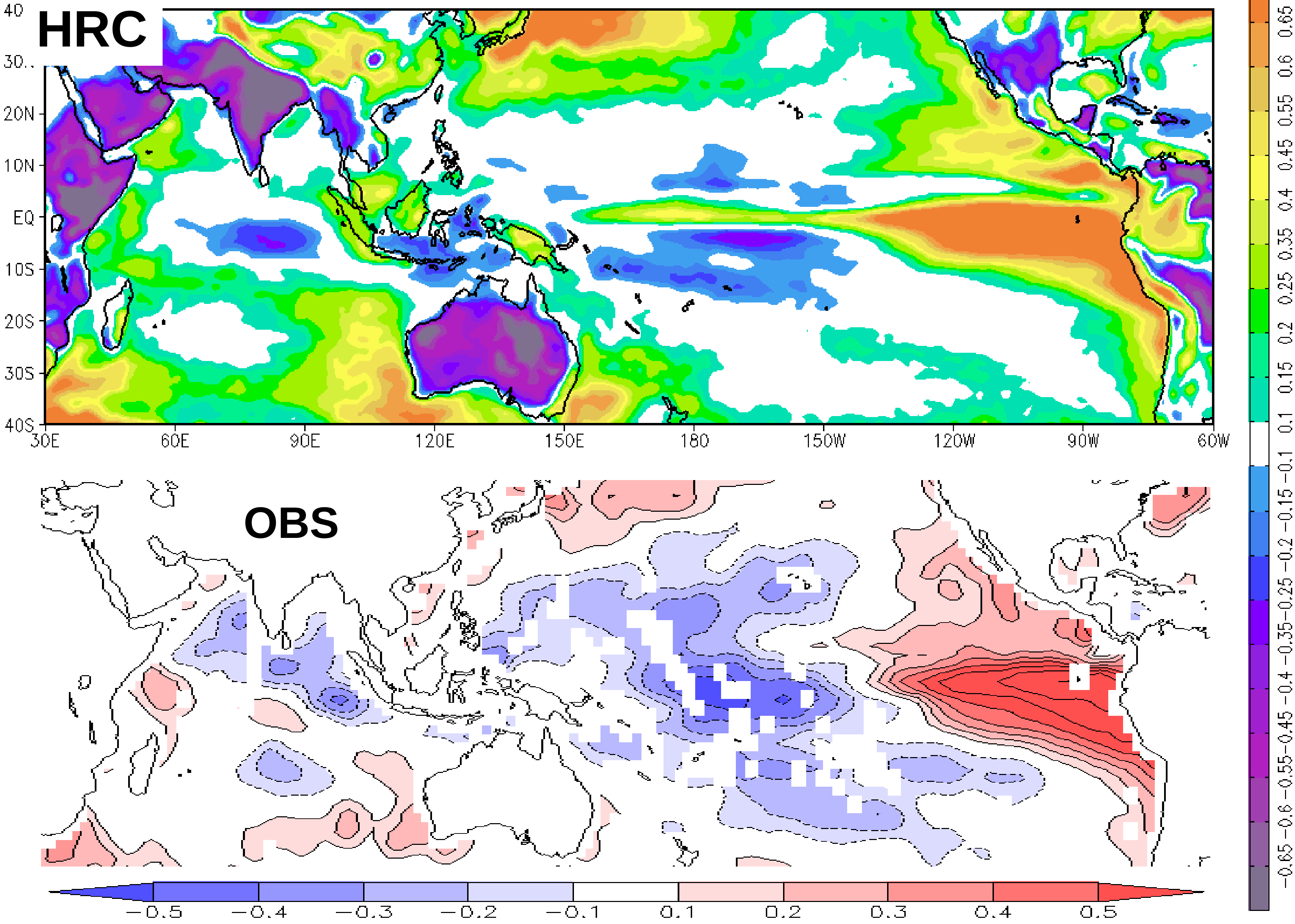
Local SSTA-Latent Heat Flux Correlation

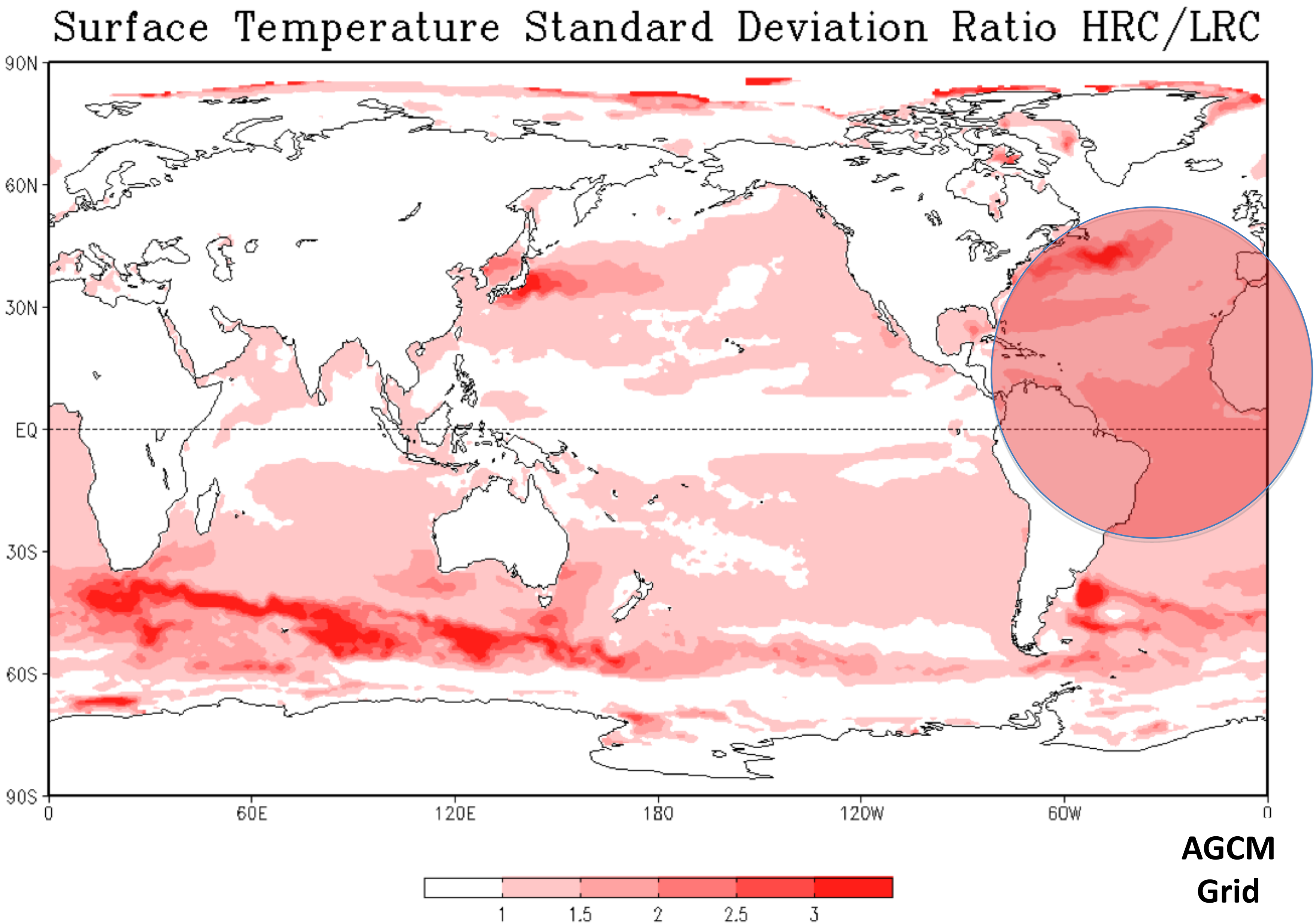


Local SSTA-Latent Heat Flux Correlation



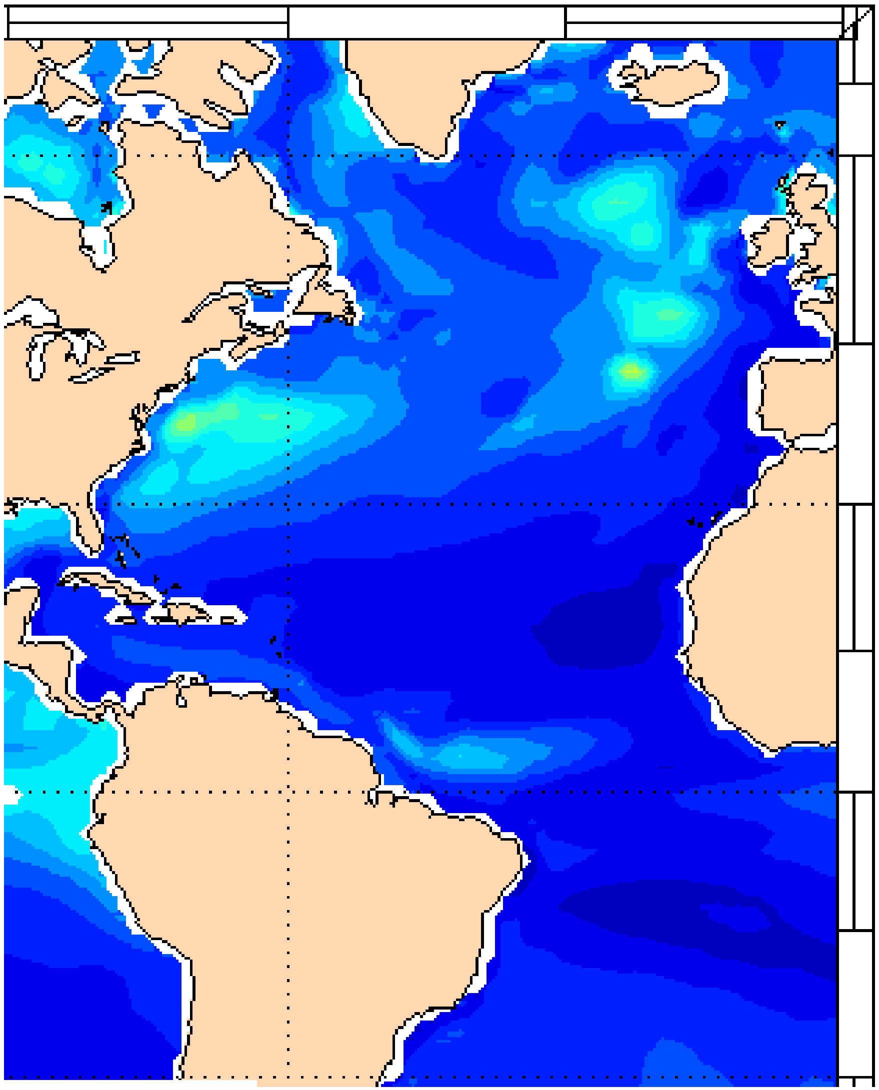
Local SSTA-Latent Heat Flux Correlation



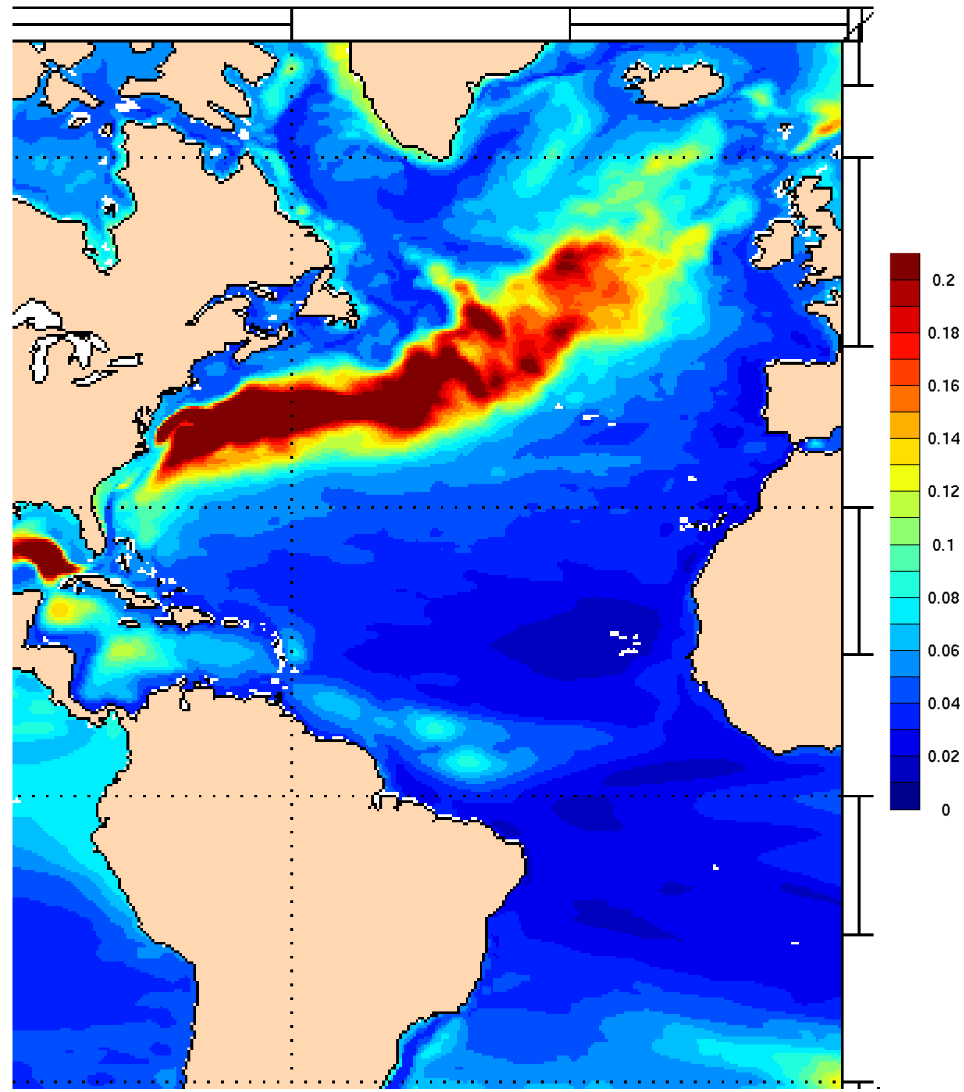

Surface Temperature Standard Deviation Ratio HRC/LRC
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
1
1.5
2
2.5
3

AGCM Grid

Sea Surface Height Standard Deviation

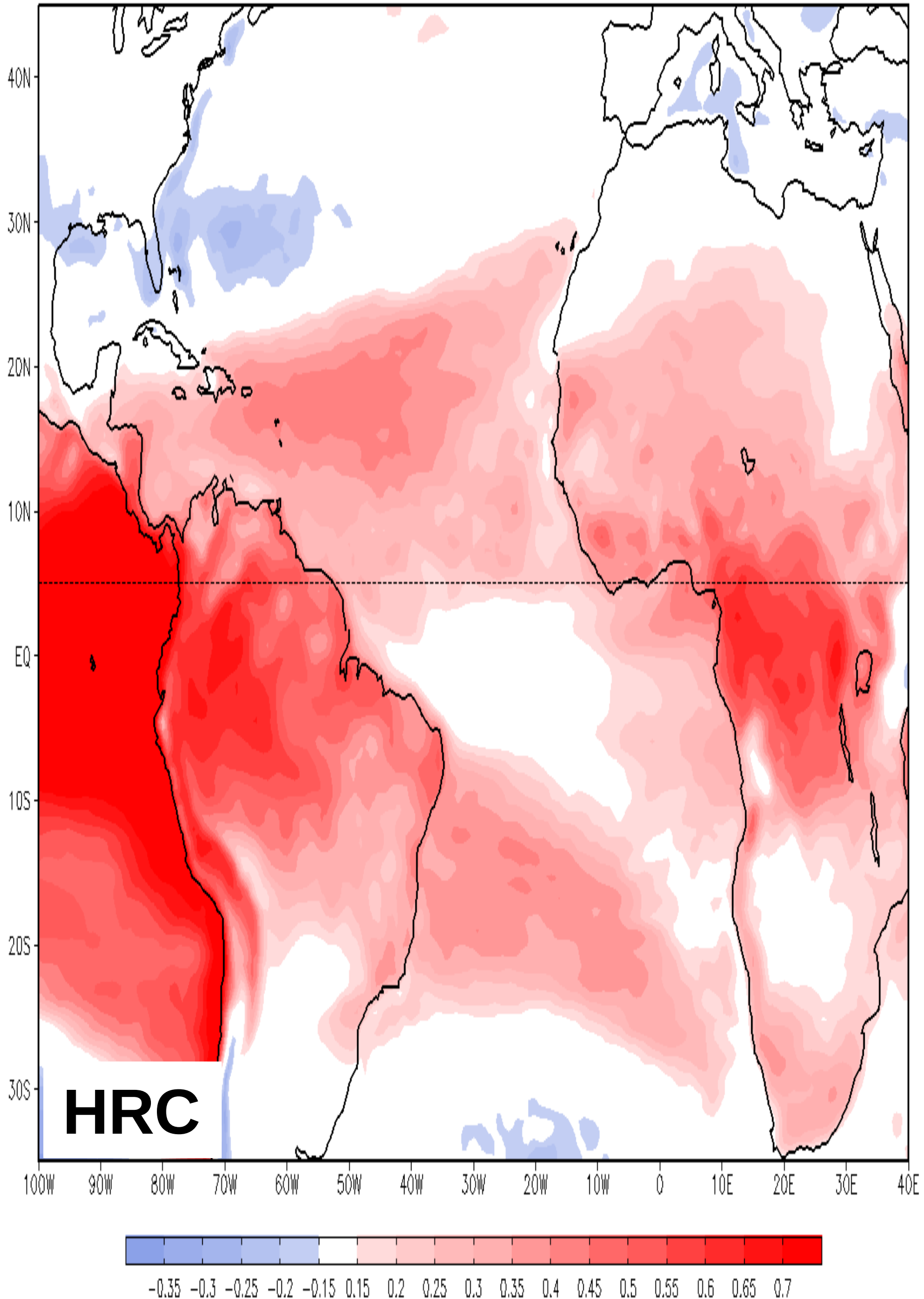


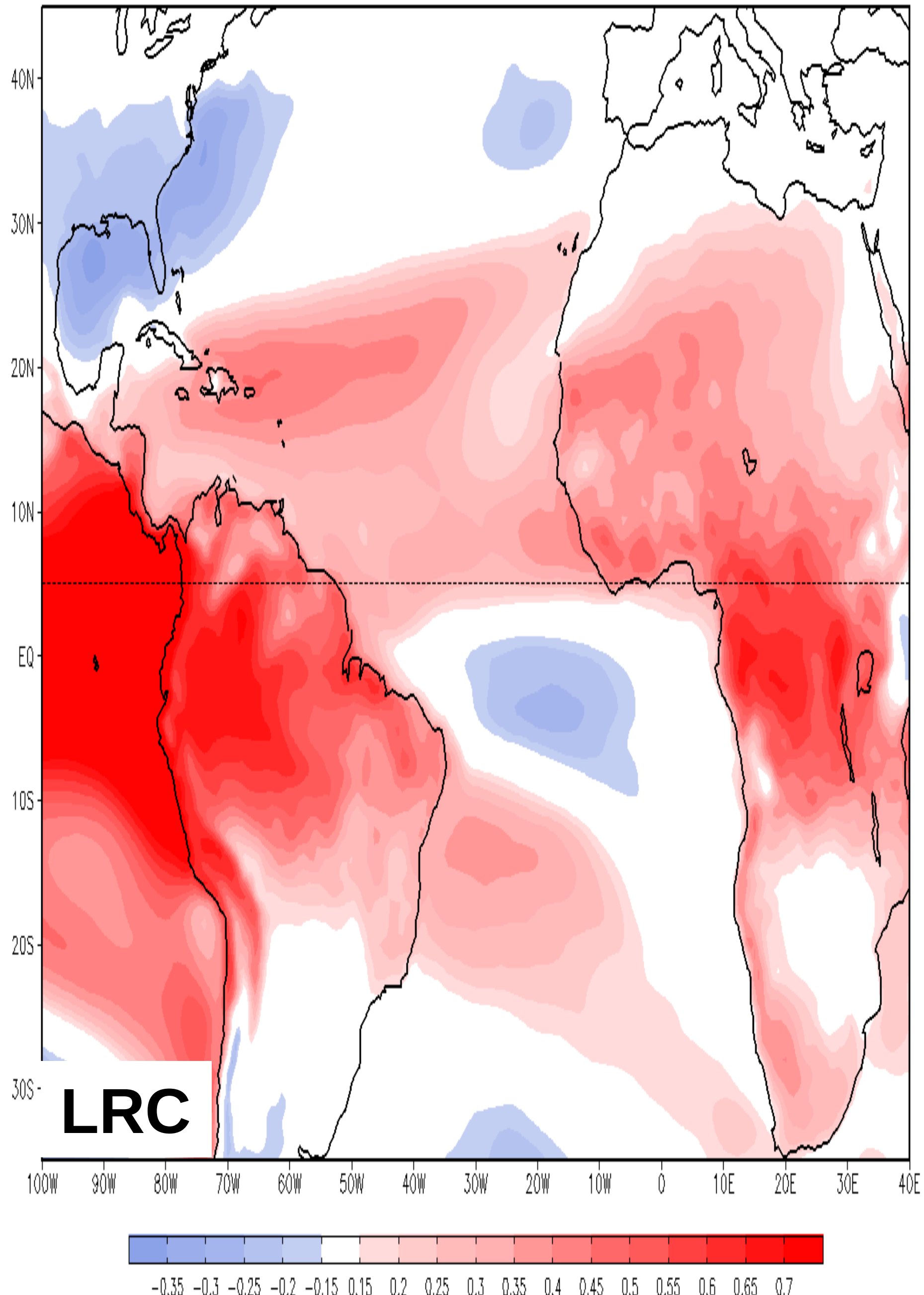
LRC SSH



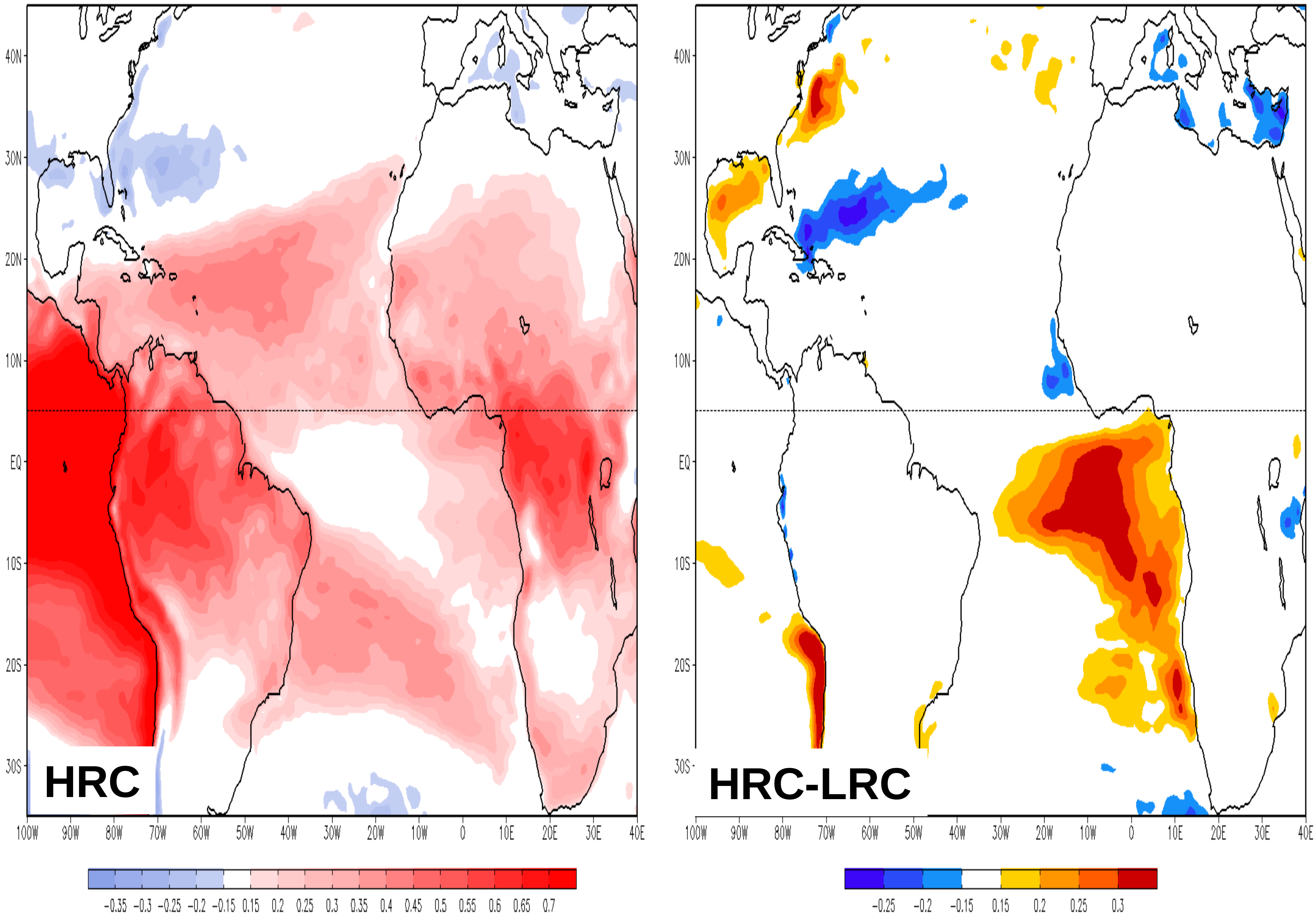
HRC SSH

Local SSTA Co-Variability with ENSO

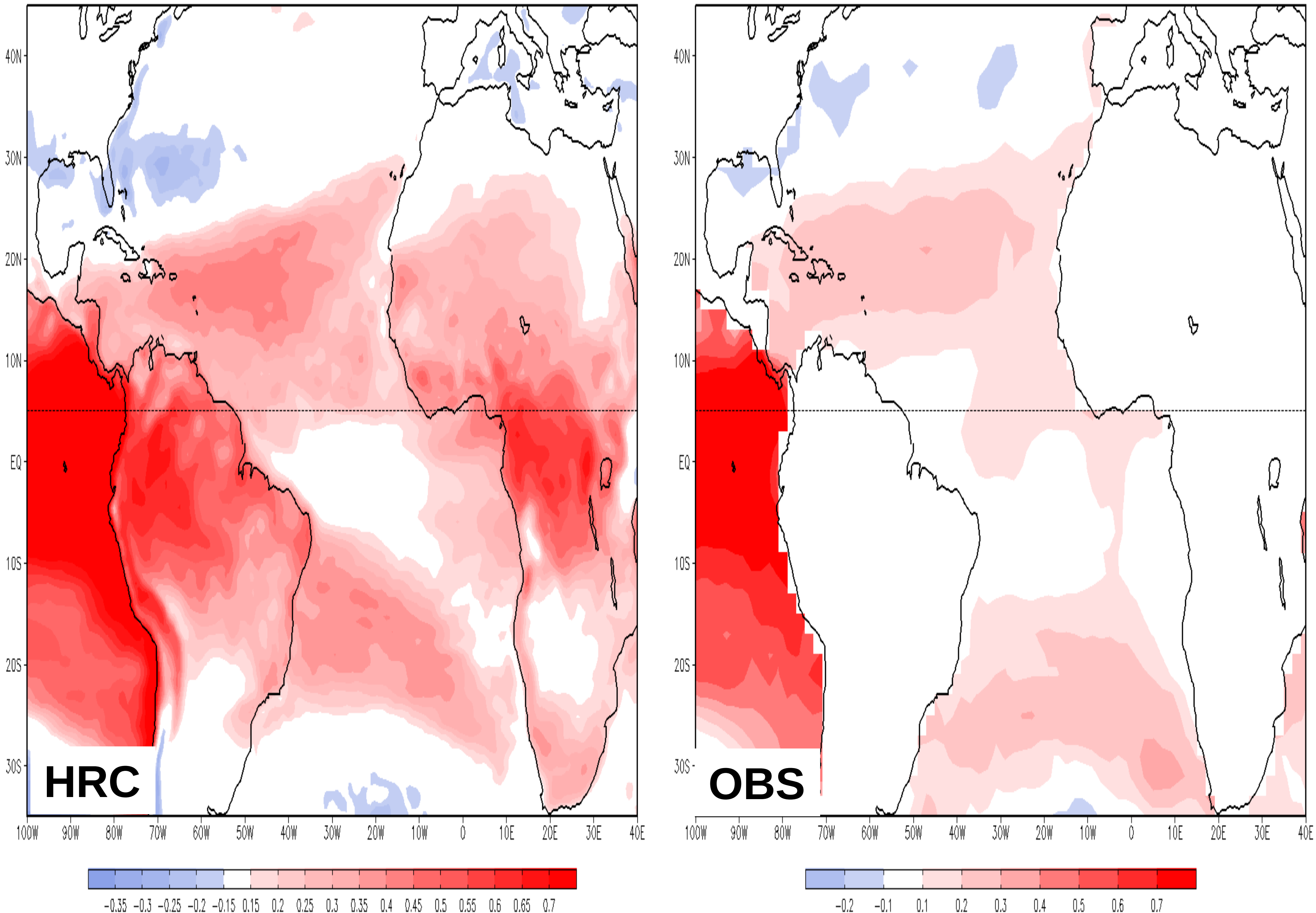




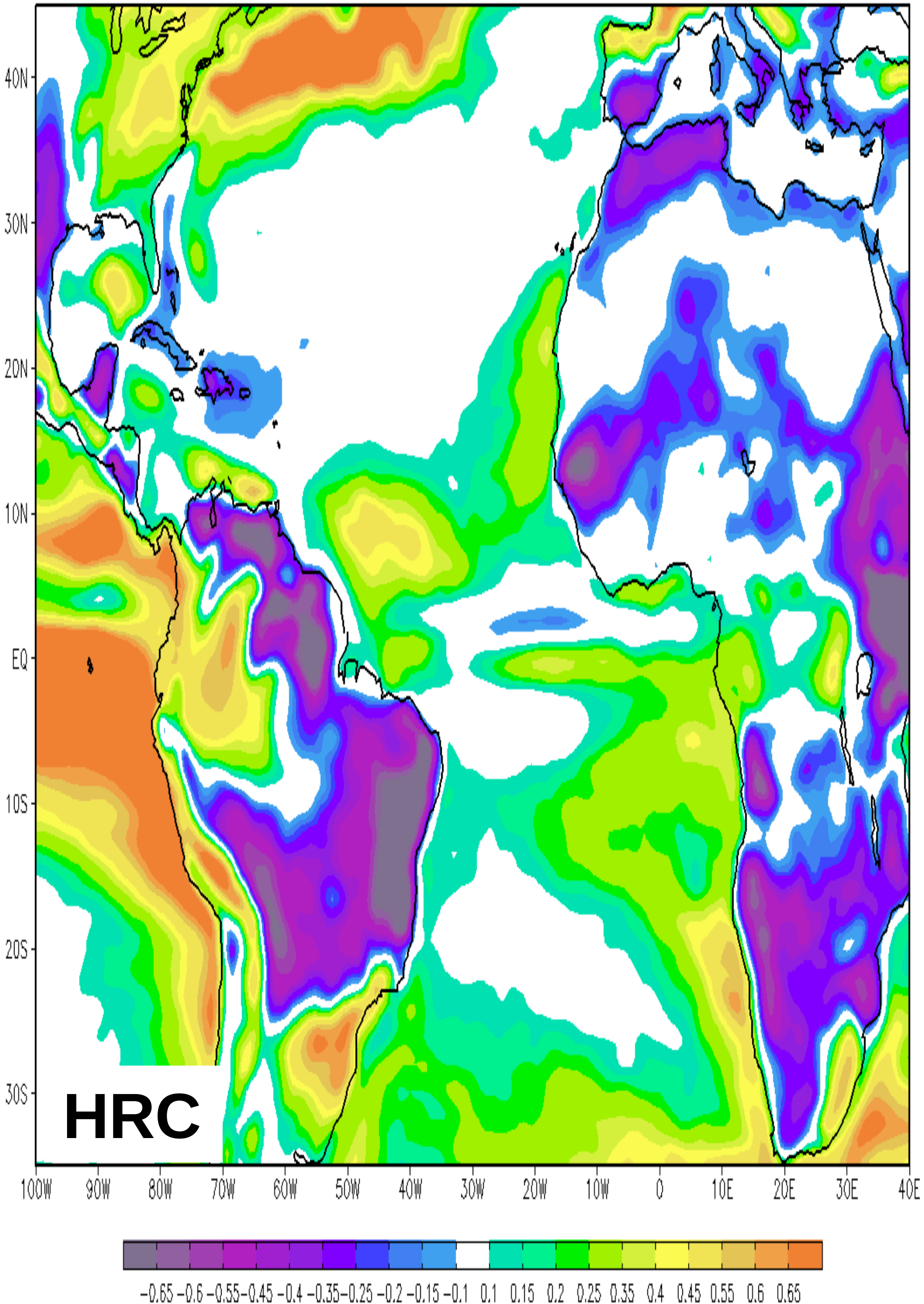
Local SSTA Co-Variability with ENSO

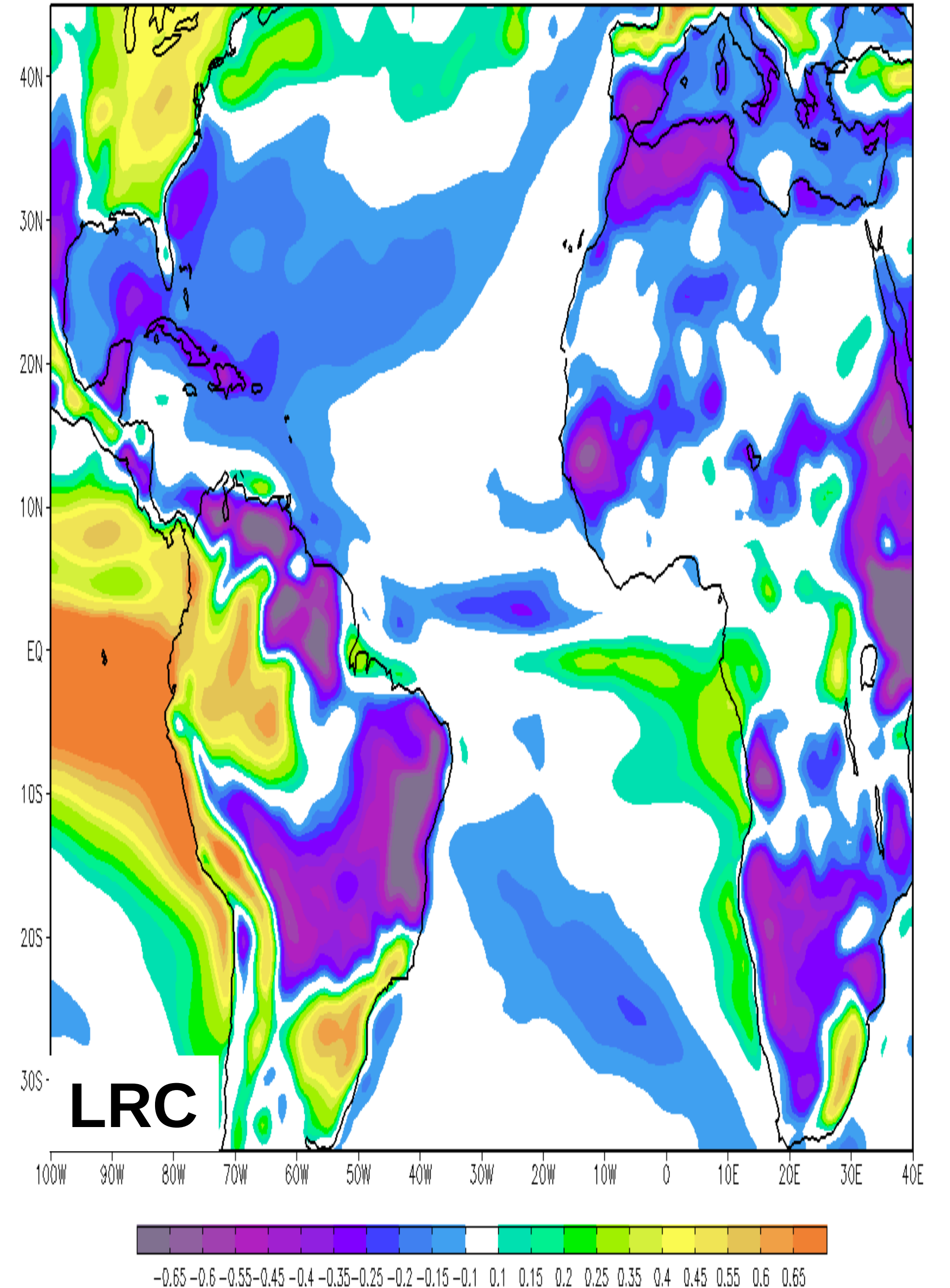


Local SSTA Co-Variability with ENSO

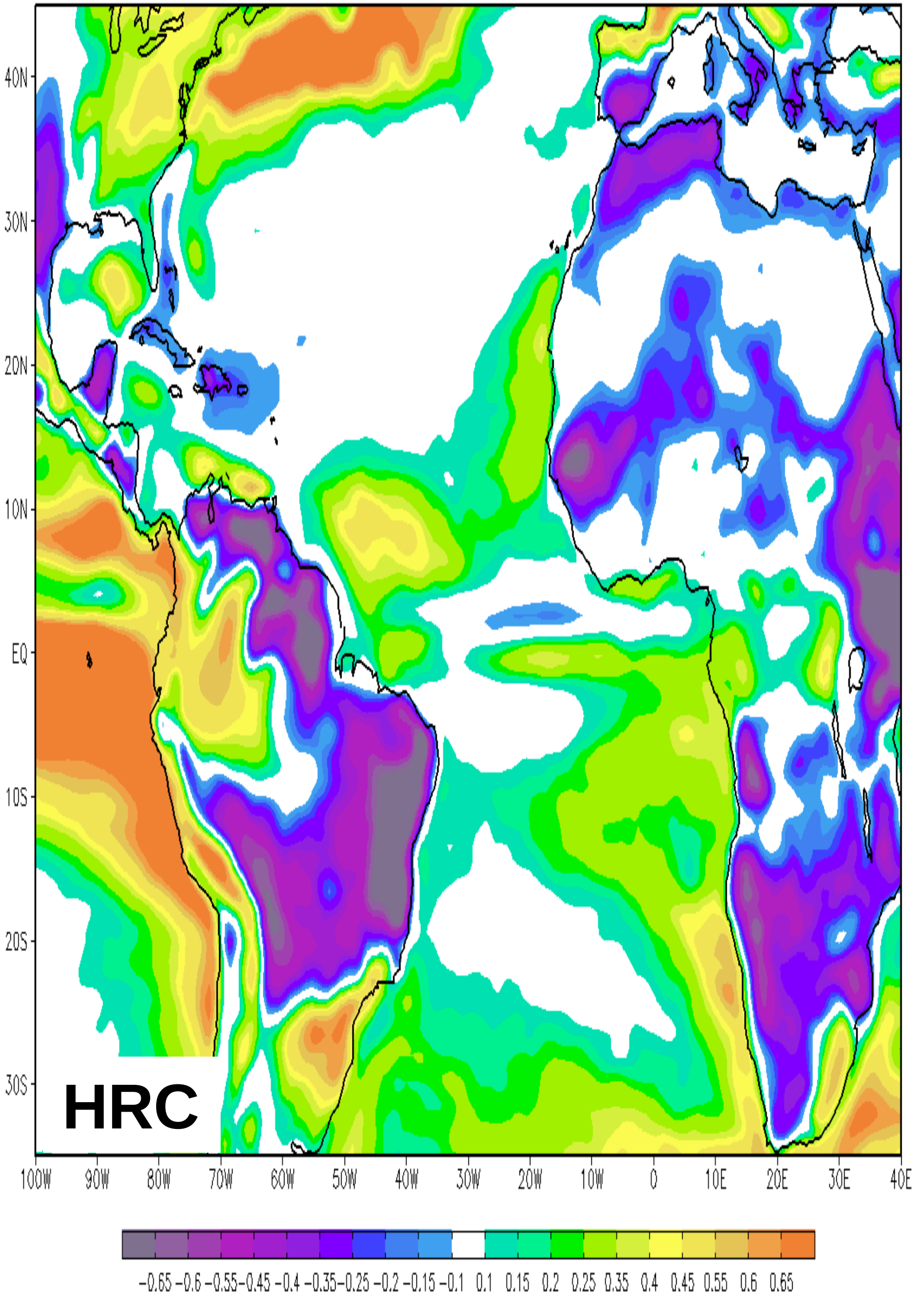


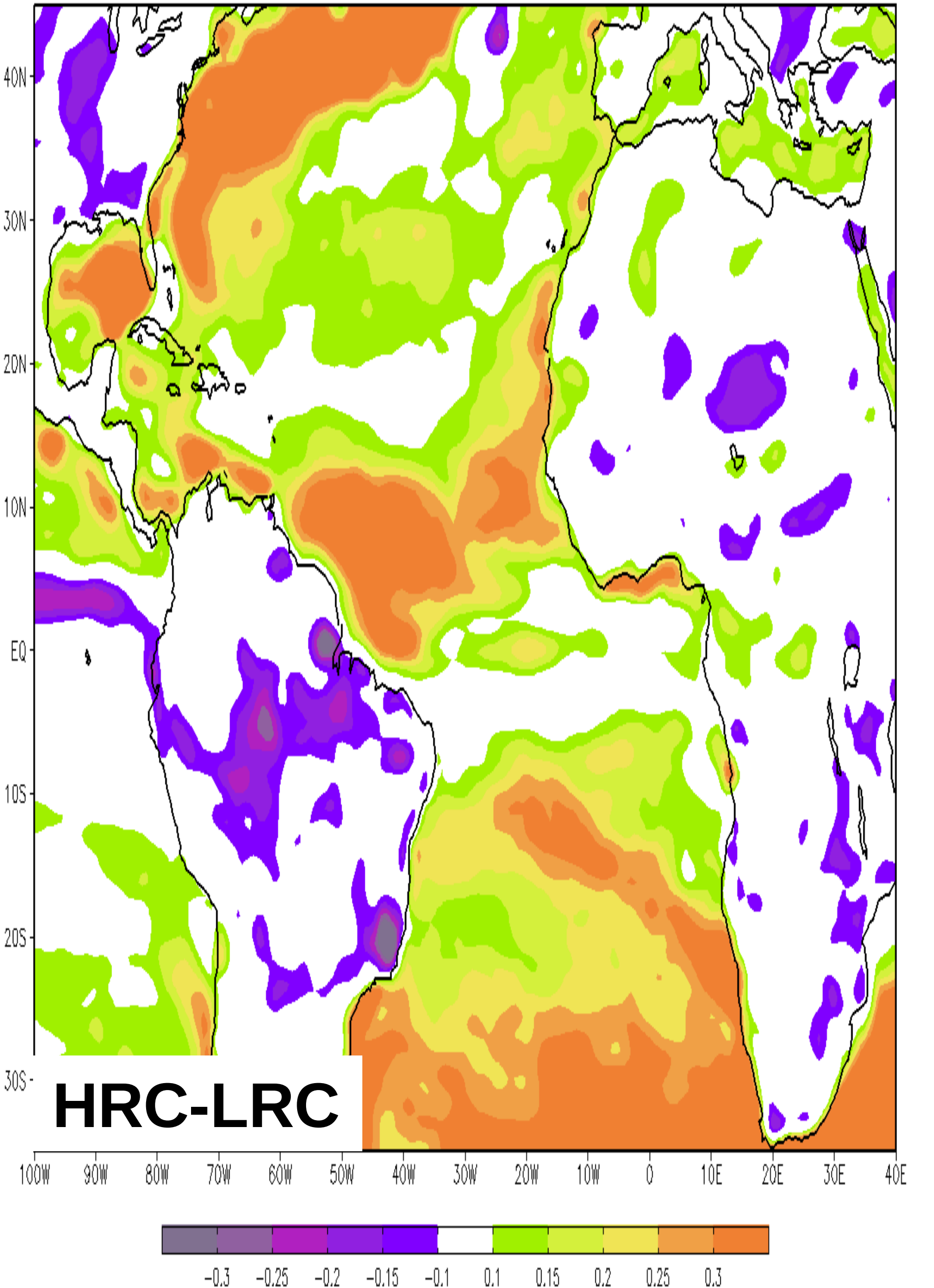
Local SSTA-Latent Heat Flux Correlation



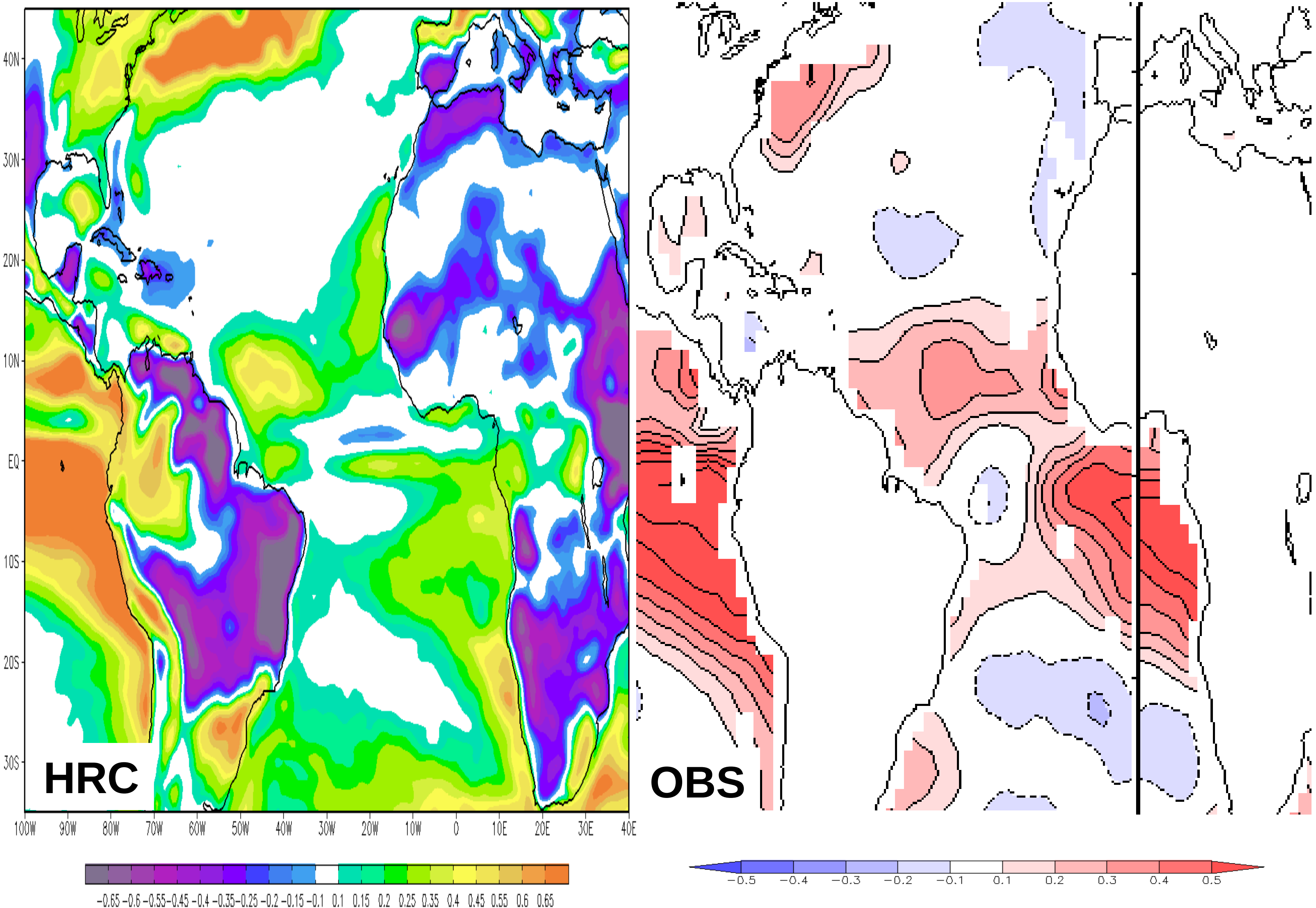


Local SSTA-Latent Heat Flux Correlation



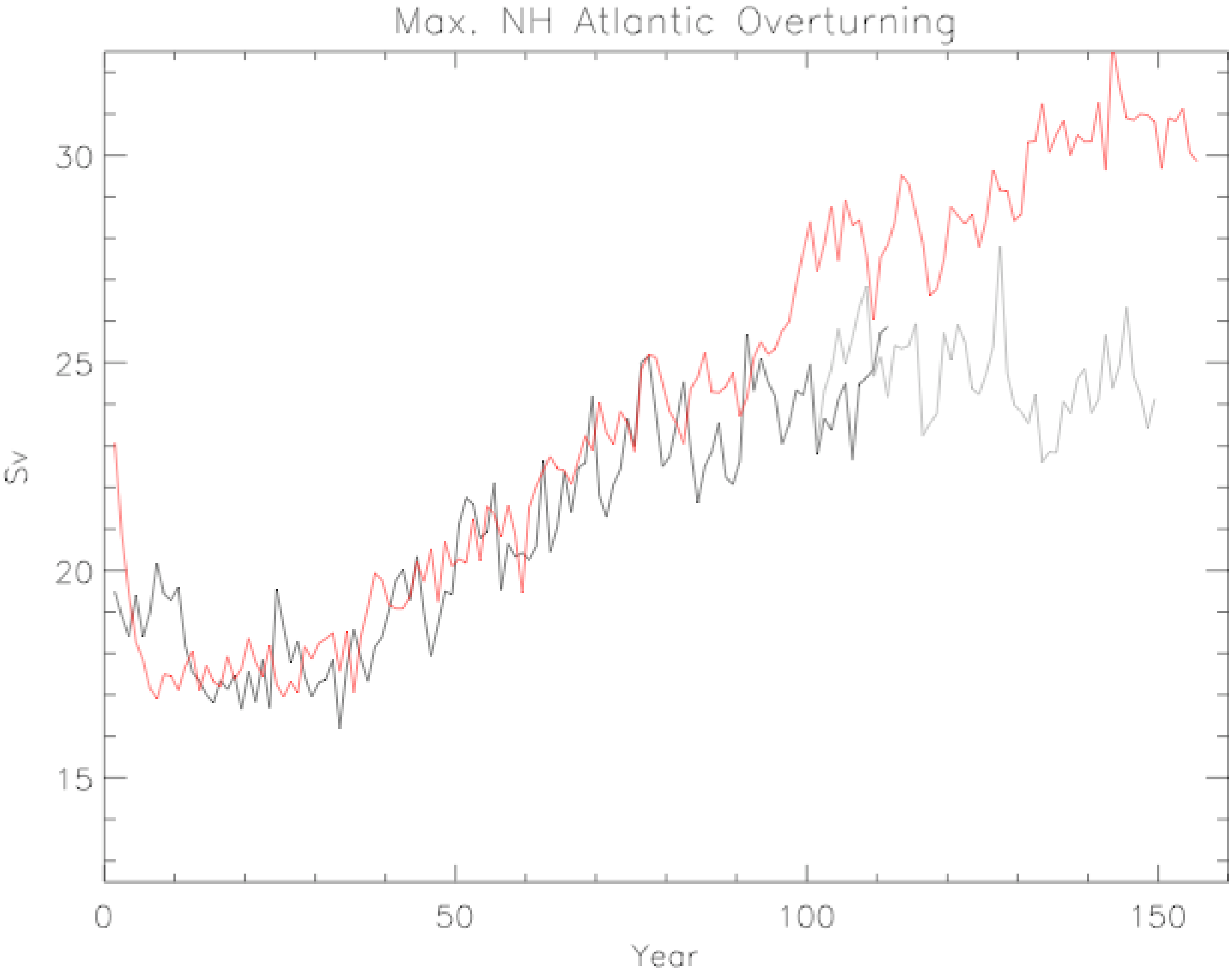


Local SSTA-Latent Heat Flux Correlation

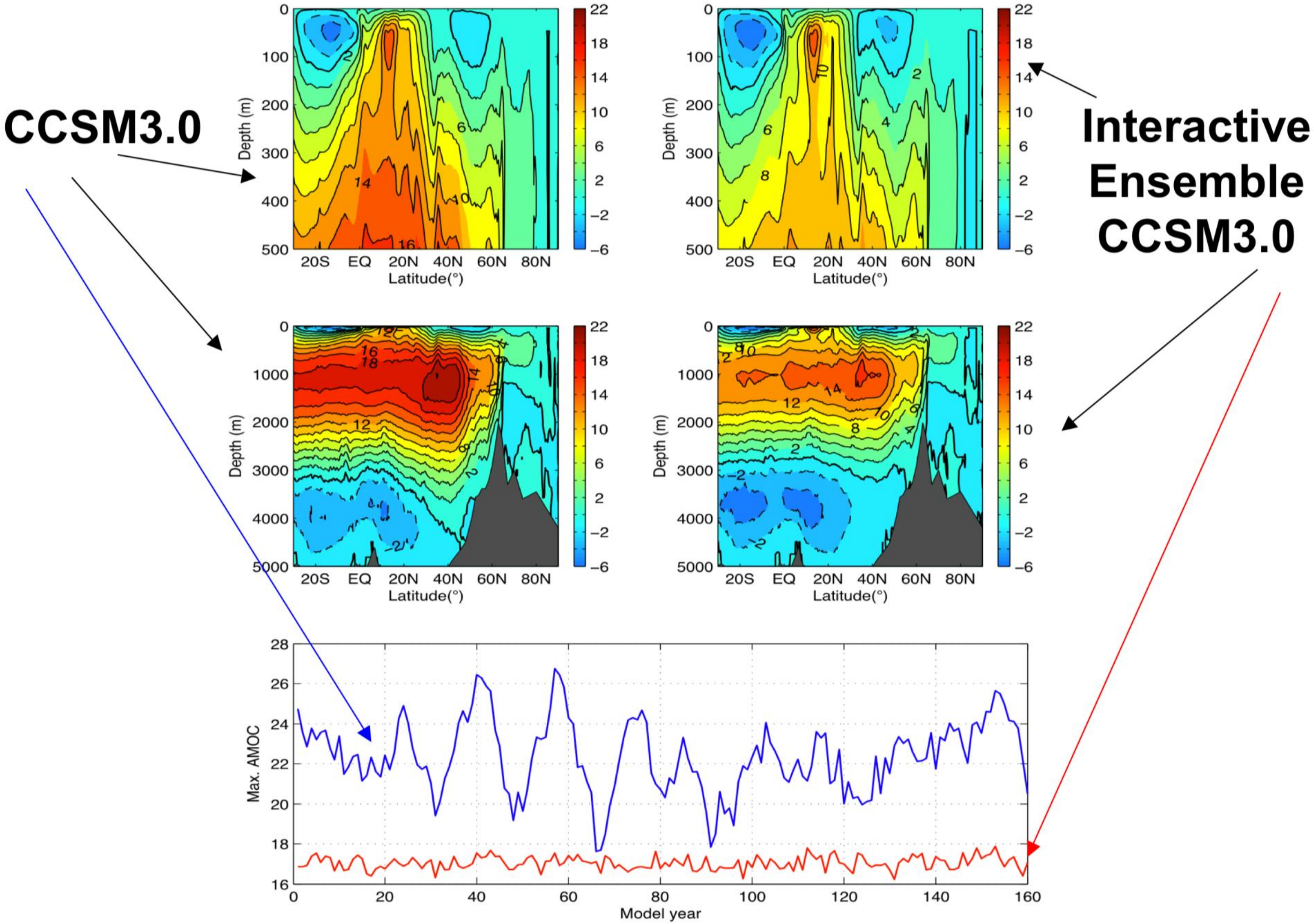


Outline

- CCSM4*
  - Atmosphere: 0.5x0.5
  - Two Versions: 1x1 [LRC] and 0.1x0.1 [HRC*]
  - Initialization: Spun-Up Ocean, Interpolation
- Analysis To Date Largely Focused on Global Climate and Air-Sea Feedback
  - Global Perspective
  - Regional Highlights: North Atlantic, North Pacific, Tropical Pacific
  - Coupled Feedback: Does the Coupling Matter???
- Movie, Future Work and Remarks

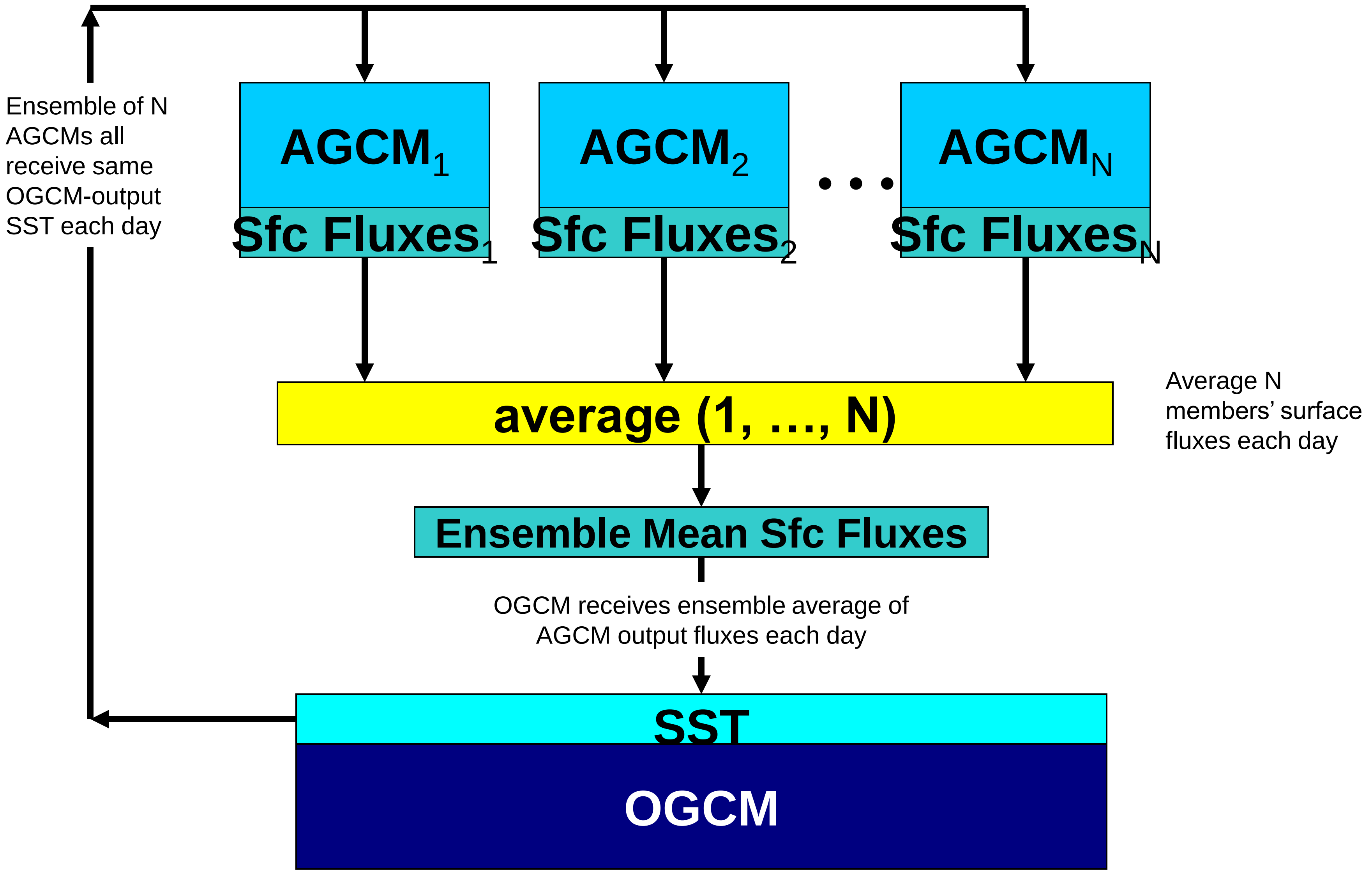

Max. NH Atlantic Overturning
Sv
Year
15
20
25
30
0
50
100
150

Future Work – Mechanism for AMOC

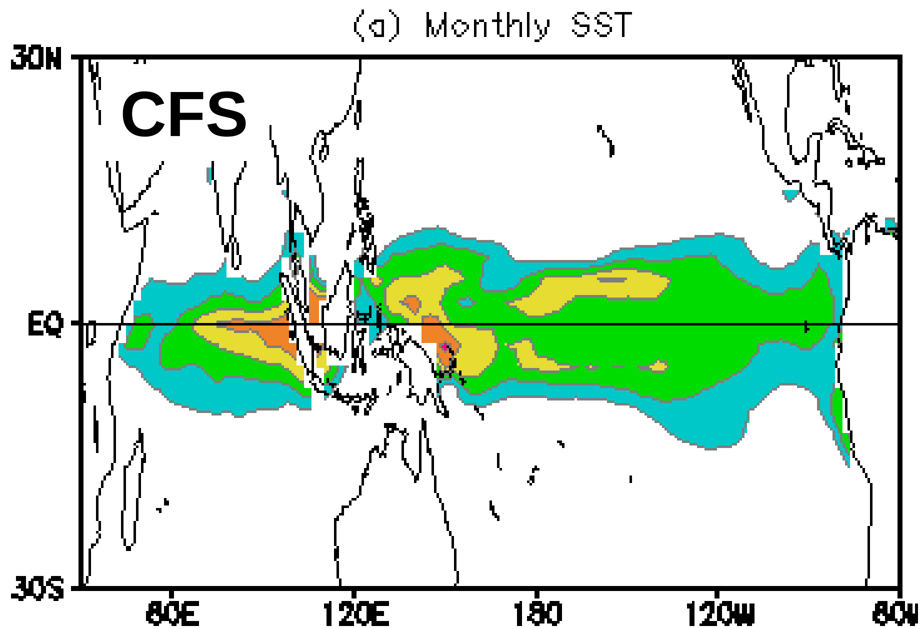


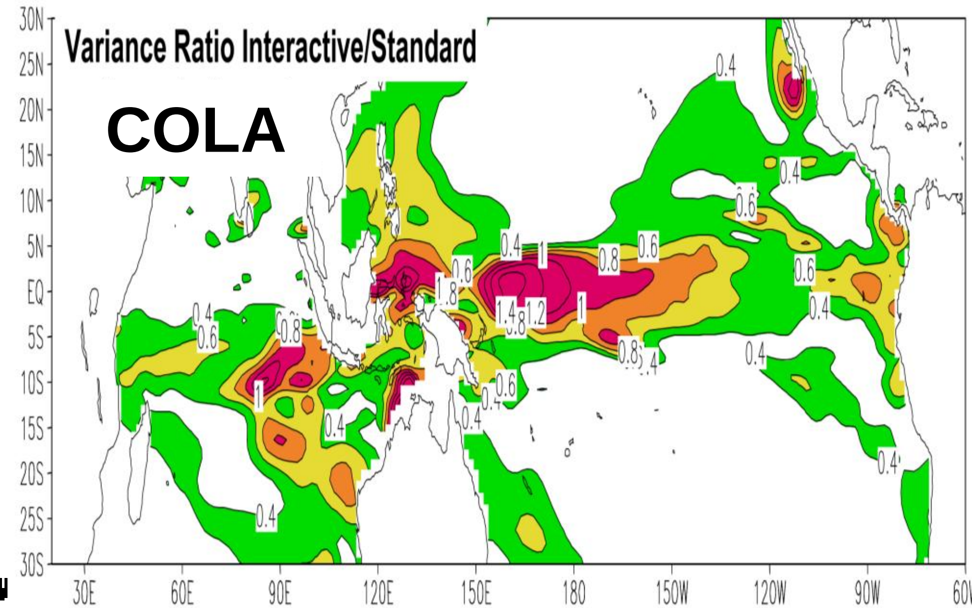
Concluding Remarks

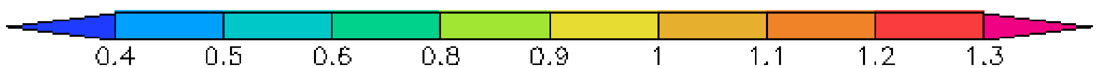
- **Motivation:**
  - **Scale Interactions – How Do Ocean Eddies Impact the Large Scale Climate?**
- **Eddies Affect Large Scale Mean Climate**
  - **Significantly Warmer Climate**
  - **Noted Differences in North Atlantic SST, Rainfall and Current**
  - **North Pacific – Rainfall Differences Relatively Small**
  - **Tropical Pacific: Reduced Double ITCZ, Enhanced Monsoon, Modest Changes in Stratification**
- **Variability and Air-sea Feedbacks**
  - **Enhanced Variability in the Extra-Tropics**
  - **Reduced Variability in Tropical Pacific and Indian**
  - **ENSO Weakens, Shifts Eastward**
  - **Changes in ENSO-SSTA Teleconnections**
  - **Much Stronger Coupling Between Heatflux and SST**



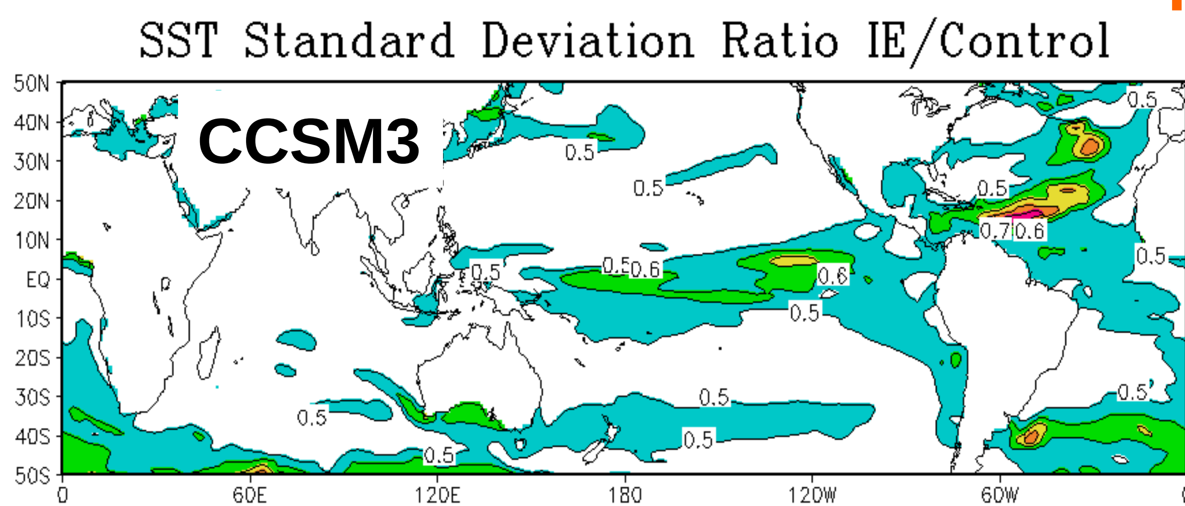
Interactive Ensemble Approach



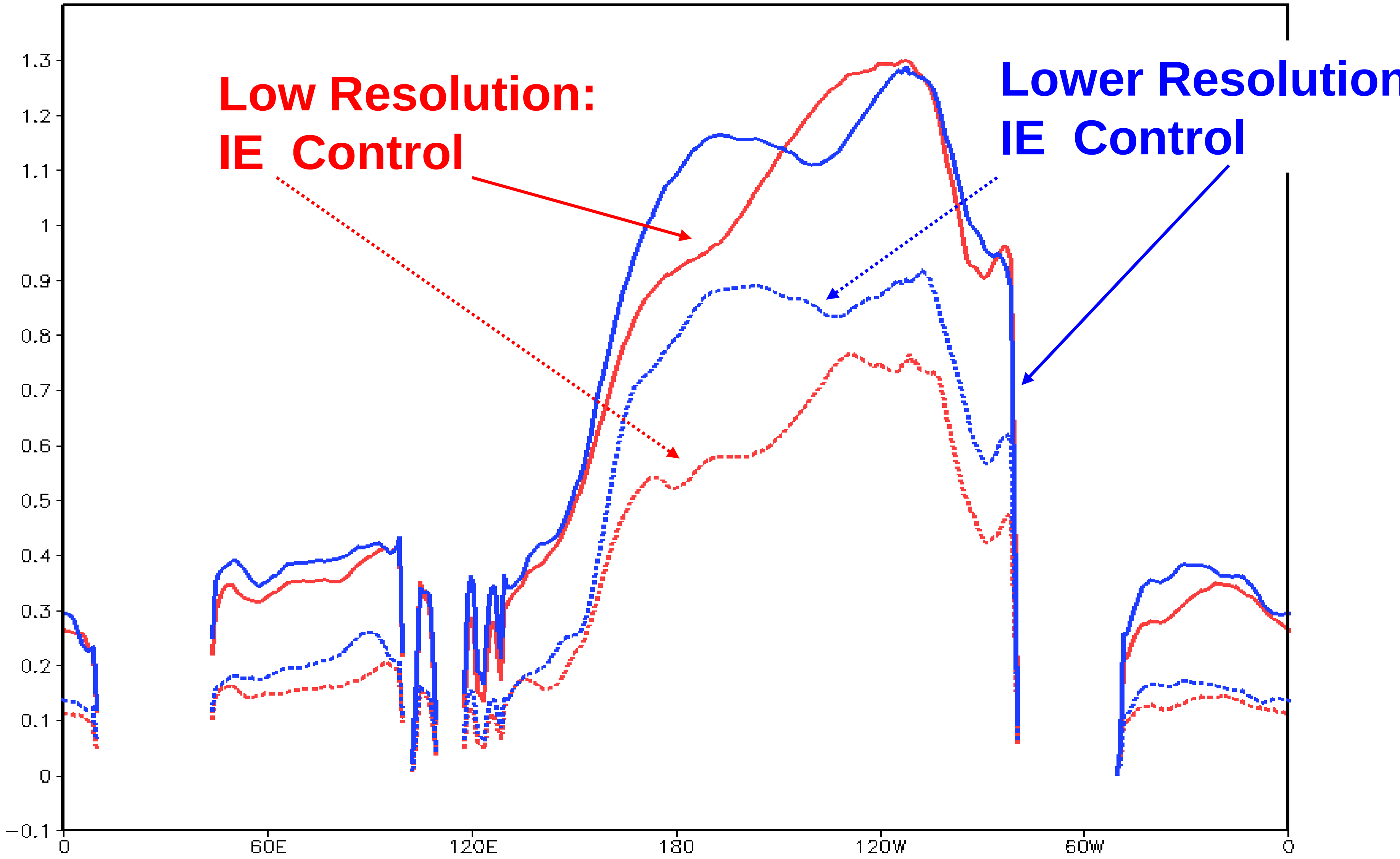




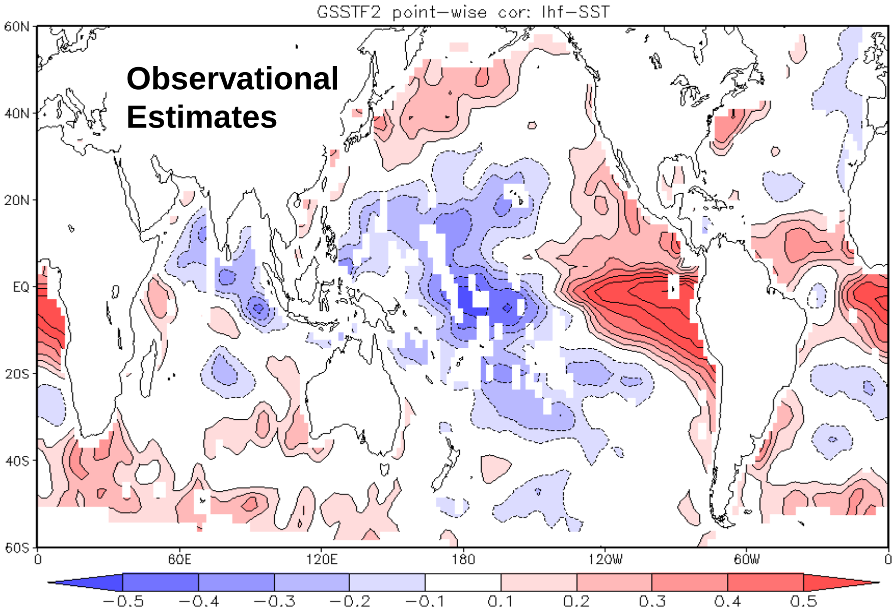
Dependence on Model Formulation

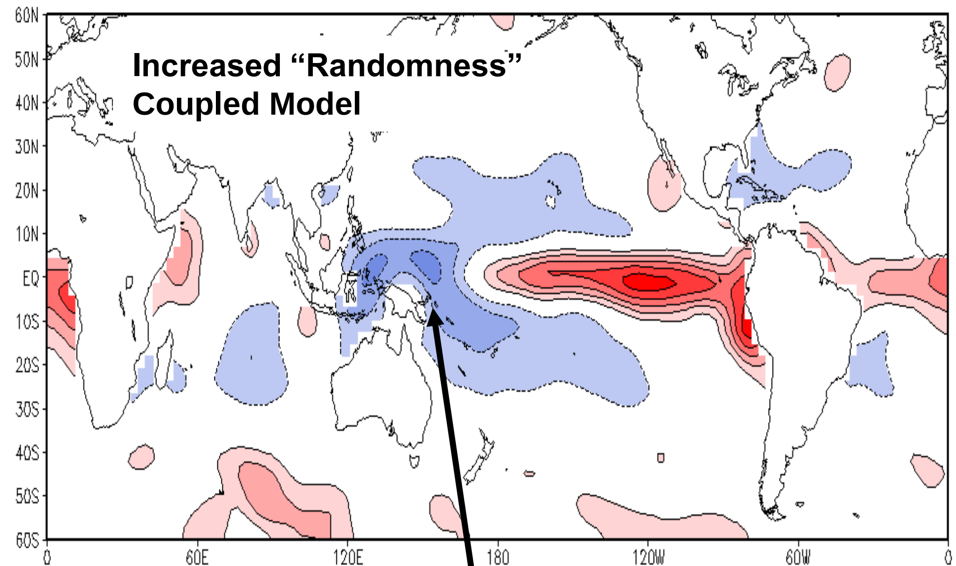


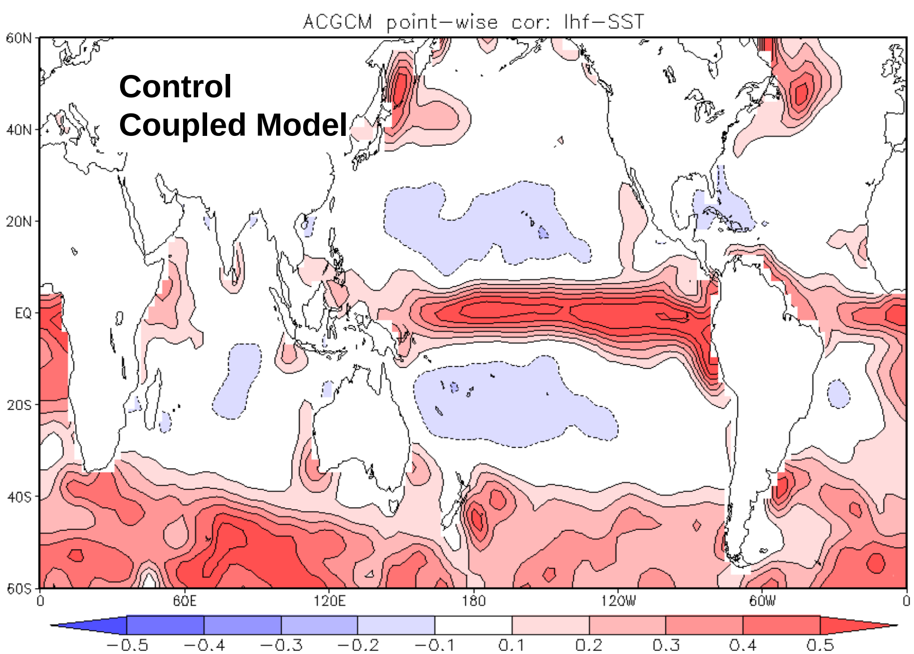
Equatorial SSTA Standard Deviation



Contemporaneous Latent Heat Flux - SST Correlati

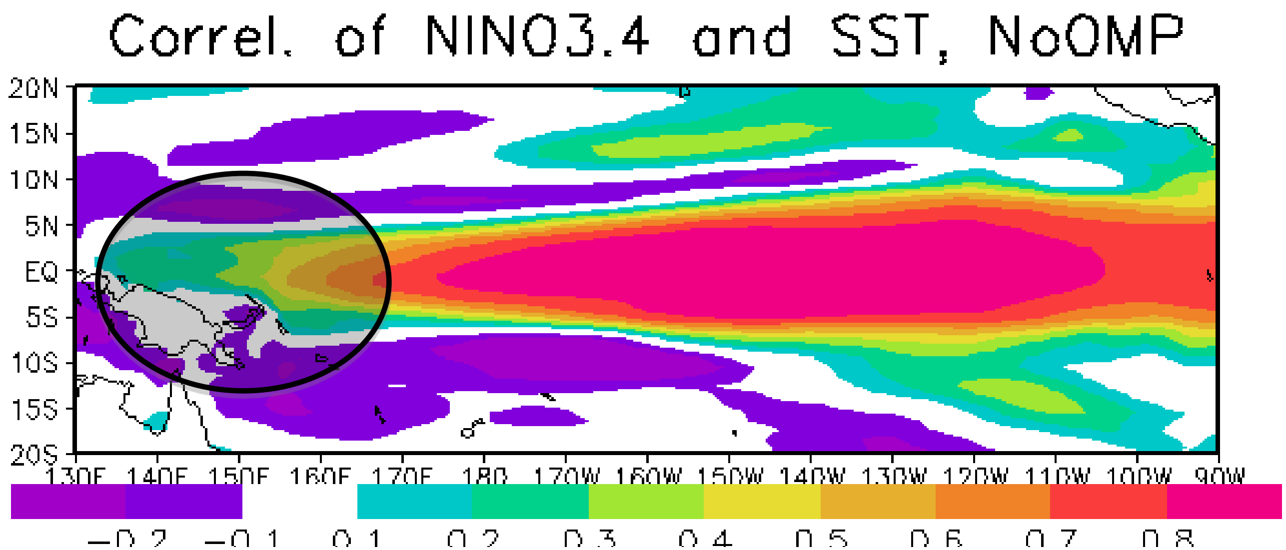




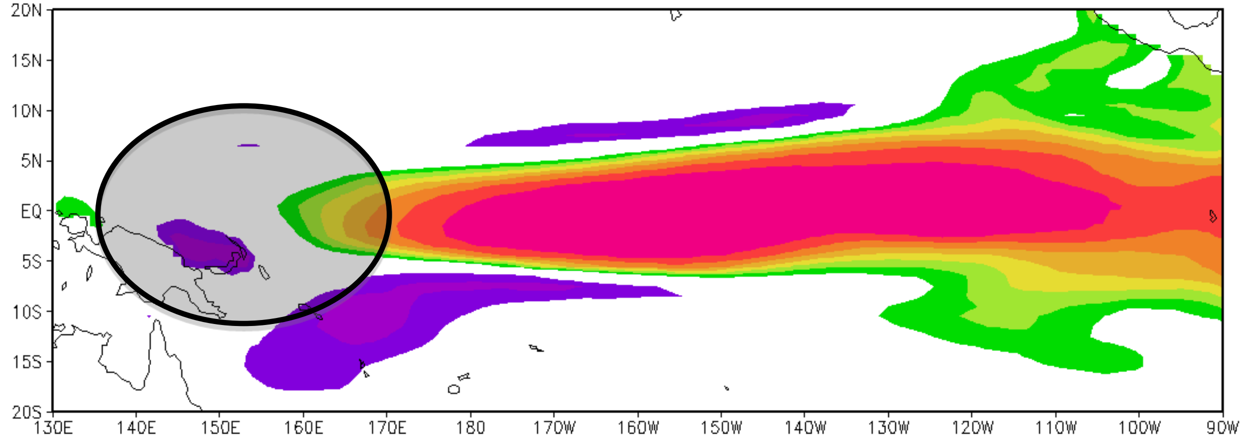


Random Interactive Ensemble
Increased the Whiteness of th
Atmosphere forcing the Ocea

CCSM3.0 Control



CCSM3.0 Random Interactive Ensemble



CCSM3.0 Random Interactive Ensemble